PROMOTING YOUNG KENYANS' GROWTH IN LITERACY WITH EDUCATIONAL TECHNOLOGY: A TALE OF TWO YEARS OF IMPLEMENTATION

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Promoting young Kenyans' growth in literacy with educational technology: A tale of two years of implementation

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Abstract (max.120 words)

This two-phase study was designed as a quasi-experiment to learn about the impacts of the interactive early literacy software, ABRACADABRA, and the digital library, READS, on primary students' reading abilities and reading instruction in Kenyan schools. For more than a term 1,899 students from 48 classes learnt to read with ABRA-READS. A standardized test detected significantly higher gains for the experimental students' than for the control group. ABRA-READS students also outperformed control students on the core exams. The system of ABRA-READS training and support coupled with the software implementation yielded some positive albeit modest shifts in reading instruction. Building the capacity of schools and teachers will enable students to benefit from the inputs of ABRA-READS after the research ceases.

Highlights

- ABRA and READS instruction is better than regular instruction on reading
- ABRA and READS effects on reading transfer to other subject areas
- ABRA and READS are effective when implemented in authentic Kenyan classroom context

Keywords:

literacy, interactive software, digital stories, Kenya primary education

1. Introduction

A quality education has been defined as one of the universal Sustainable Development Goals (SDGs) ratified in 2015 by the United Nations community. For developing countries where human and financial resources are scarce and little consensus exists about how to attain these goals, improving the quality of education remains a major challenge. However, as computer technology is becoming cheaper and increasingly wide-spread, education communities, including policy-makers and practitioners, view it as a means to help address the issue. Moreover, research has confirmed the potential of digital technology to enhance both teaching and learning by increasing students' foundational skills (for instance, Cheung & Slavin, 2012) and scaffolding teachers' instructional practices (for instance, Angeli & Valanides, 2009). In the contexts where educational resources are sparse, the possible benefits of technology use become particularly relevant. This paper reports the results of two years of a multi-year study in one country in Sub-Saharan Africa where research-based and evidence-proven multimedia software is being used to equip teachers with effective instructional strategies to improve English literacy levels among elementary students.

1.1. Study background

Along with food and water, shelter, health and wellbeing, personal safety and peace, education has become an international imperative where improving literacy throughout life is a driver for sustainable development (SDG, UNESCO, 2015). Conversely, the costs of a poor education are staggering: poverty, crime, poor health, and a host of other social and personal ills are exacerbated by the inability of people to command basic literacy skills (Martinez & Fernandez, 2010). Although remarkable progress has been made in improving literacy rates and levels of educational attainment on the global scale, there remain 750 million adults – two-thirds of whom are women – who cannot read and write; there are also 250 million children who cannot decipher a single sentence, even though many have spent years in school (UNESCO IUS, 2017).

The challenge of improving the quality of education persists because in the contexts of developing countries educational resources are limited, especially when there is little or no special training for lower primary teachers who are expected to teach beginning literacy and other essential competencies (Ono & Ferreira, 2010; Akyeampong et al., 2012). In their review of the literature on pedagogy, curriculum, teaching practices and teacher education in developing countries, Westbrook et al. (2013) found that teachers over-relied on basic recall, rote learning, memorization, repetition, and recitation in their practice. A major recommendation of the review was that teachers needed to be able to use communicative strategies encouraging pedagogic practices that are interactive in nature as they are more likely to be effective for student learning. In a meta-analysis of randomized experiments aiming at improving the quality of the primary schools in developing countries, McEwan (2015) indicated that successful interventions worked to develop teachers' capacity to deliver effective classroom instruction, relying especially on educational technology and small group learning.

1.2. Effective English literacy instruction

Literacy research generated in the past couple of decades has pointed to what effective reading instruction entails. Successful reading requires the development of decoding skills, vocabulary, fluency and comprehension and the development of learning strategies to construct meaning from the text (for instance, National Reading Panel, 2000; RAND Reading Study Group, 2002). The research emphasizes the importance and value of teaching these skills and strategies actively, deliberately and systematically, advancing from easy to more difficult skills where the link to comprehension goes from phonological processing through word identification to comprehension itself. For instance, the initial instructional focus on symbol-sound relations progresses from high-frequency one-syllable-easy-to-decode words, to multi-syllabic words and to word-reading in conjunction with its spelling and meaning. Further, the instruction focuses on skills to read and understand a sentence as a whole thought, to arrive finally at understanding a passage and a longer text.

As readers advance, their reading comprehension becomes associated with the active use of meta-cognitive strategies that help regulate the process of knowledge and meaning construction. Cain, Oakhill and Bryant (2004) pointed out that it is the active use of higher-level strategies that predict reading comprehension beyond word recognition and language ability. These strategies include knowledge of text structure and its features, inference making as an ability to discover the causal structure of a narrative text, and comprehension monitoring as a skill to verify understanding and make repairs where meaning breaks. Strong reading instruction also develops a set of sustainable drivers, which an independent reader typically possesses, such as motivation (for instance, Guthrie, et al., 2007) and reading enjoyment (for instance, Clark & De Zoysa, 2011). Finally, effective teaching of reading fosters adequate on-task activities, establishes connections across curricular themes, and also depends on the strong link between home and school (Hall & Harding, 2003).

Although the bulk of the reading research has been generated by and for the developed world, the findings and recommendations are pertinent in the context of developing countries and where English is not mother tongue or a dominant language. The recent USAID landscape report (Kim et al., 2016) emphasizes the applicability of a range specific findings to the English literacy instruction in the multilingual or second/foreign language learning contexts. One of these is a need for providing sufficient instruction in mother tongue of young learners to help develop cognitive skills, which then facilitates acquisition of a new language literacy (for instance, Ball, 2011). The evidence of the transfer of literacy development between the languages of varying extent of linguistic distances have been reported (for instance, Branum-Martin, Tao, & Garnaat, 2015; Koda & Reddy, 2008). Building oral English proficiency for students who are below a threshold of linguistic competence is another pertinent finding. The evidence suggests that the instructional strategies targeting English literacy development such as decoding and comprehension are successful when they are combined with the concerted and parallel efforts to help students who have low requisite language proficiency to comprehend the text. Thus, it is critical to develop these students' knowledge of oral vocabulary and listening comprehension skills (for instance, Geva, 2006). The effective reading instruction also exposes students to good language models through the reading of books, along with the provision of access to rich vocabulary and expression. Engagement of students into cognitively demanding conversation, will also increase their language learning opportunities.

Evidently, such quality of literacy instruction involves both teacher knowledge about literacy development and their ability to adequately apply this knowledge to their daily teaching practice. Challenges with quality reading instruction in affluent schooling contexts have been well-described (for instance, Allington, 2011; Stanovich, 2009); thus, it comes as no surprise that effective teaching of reading continues to be weak in low-resource settings (Dubeck, Jukes, & Okello, 2012; Lussier, 2015). The USAID report on early literacy (Kim et al, 2016) recognizes computer technologies for the potential it offers to the educational contexts where a quality teaching workforce falls short.

1.3. ICT for literacy

The two major advantages that ICT may provide to teachers and students in the developing world include access to quality educational content, and opportunities for individualized or differentiated learning (for instance, Wagner, 2014; 2016). The systematic reviews of the technology-based instructional interventions' effectiveness in low-income educational systems (synthesis by Evans & Popova, 2016) revealed the lack of rigorous and consistent evidence about their impact on learning outcomes. At the same time, these reviews seem to agree about what the effective computer intervention looks like, highlighting its comprehensive nature. Primarily, such intervention is tailored to students' level of knowledge and skill; further, it is tied to the curriculum and lastly, it provides teachers with training and ongoing support on how to integrate the specific technology in their teaching. Kim et al. (2016) add that an effective technology-based intervention is aligned with sound pedagogical practice and can be expected only after extensive training and support on the pedagogy and use of devices and software that allow teachers to build their capacity to implement the intervention meaningfully. In other words, teachers play an even greater role in students' technology-enhanced learning than the technology intervention itself as it is they who decide what kinds of technology to employ for specific learning goals and how to best use it for achieving various pedagogical outcomes (Schmid et al., 2014).

An attempt to apply a comprehensive approach to the implementation of the literacy software in Kenyan public primary classrooms was done in own feasibility research (Abrami et al., 2016). The 13-week literacy intervention encompassed regular access to the software when grade 2 students were bussed once a week to a reliable computer lab in a better resourced school. The teachers were trained on how to implement the software in their English language teaching. Ongoing technical and pedagogical support was provided then both to teachers and students including help embedded in the tool and that provided by the experts assisting in the lab. This led the experimental students achieving significantly greater gains in reading comprehension than their peers from the control classes exposed to the routine recitation instruction.

This paper reports the results of a follow-up, fully-fledged project targeting a high-quality teacher implementation of the literacy software in their own classrooms. We refined and further developed the initial multi-component intervention model, brought it into the authentic context of schools and examined its impact with regard to classroom instruction and student literacy.

More precisely, we explored the following questions:

1. How does the literacy software and associated professional development and support impact Kenyan students with respect to the learning of essential educational competencies? Do these effects vary across learning contexts (e.g. grade levels) and student characteristics (e.g., gender, prior achievement)?
2. What are the impacts of the literacy software and associated professional development and support on Kenyan teachers' instructional practices and professional skills? How do teachers adapt and adjust their implementation of the software?

2. Methods

2.1. ABRA and READS software

One of the Learning Toolkit Plus suite of learning software tools, *ABRACADABRA* (A Balanced Reading Approach for Children Always Designed to Achieve Best Results for All, ABRA) is an online application that provides an engaging interactive environment for learning literacy for early elementary school-aged children. ABRA consists of student, teacher and parent modules. ABRA's Instructional or Student Module contains a variety of instructional materials including 33 alphabetic, fluency, comprehension, and writing activities, many at different levels of difficulty and complexity. These instructional activities are linked to 20 interactive stories of various genres and 15 stories written by students each narrated by a Canadian, Australian and a Kenyan.

The research-based nature of ABRA ensures the systematic integration of the cumulative evidence on the major skills and associated sub-skills in the areas needed by successful readers. Based on the tenets of a balanced literacy philosophy, ABRA emphasizes a harmonious balance between code-emphasis and a literature-rich context. This allows students to explore their interests by applying a large repertoire of strategies that can be readily accessed when meaning breaks down (Pressley, 2002). The balanced literacy approach means that instructional activities are designed within the context of story texts and vice versa.

The gaming elements of ABRA are features designed to engage children in reading and writing and to increase their motivation. When students complete an activity, they are rewarded with a mini-game. At times, the game is at the core of the pedagogical structure of the activities. ABRA characters, each linked to a literacy skill, also add to its game-like feel. Each character has a personal story the children can read or listen to, a story reinforcing the purpose and context of what students have to do in a specific activity. This underlying narrative thread also helps create a gaming experience in ABRA. The tool places a strong emphasis on students' auditory processing: instructions are provided orally with a possibility of replaying them; each story embeds oral prompts based on segmenting and blending. The ABRA characters' input is also auditory and all demos are accompanied by audio explanations. The tool is neither linear nor prescriptive in use. Students may enjoy higher degrees of autonomy as they can choose texts and activities as well levels of difficulty of the latter. Teachers, in their turn, can target specific skills for instruction as well as guide their class or individual student from basic sound and letter identification to complex tasks such as reading with the proper expression, spelling, story comprehension, and individual responses to stories.

The embedded support within the tool tailors the degree of learner scaffolding provided, as students interact with the tool. If students answer incorrectly, they are provided with visual and/or auditory guidance or can seek help. In addition, there is extensive teaching material embedded in the tool that provides just-in-time support for teachers and a rich base of resources for classroom use. The materials for teachers are accessible within the Professional Development or Teacher Module and offer explanations, lesson plans, embedded video teaching vignettes, and printable resources. A Kenyan teacher manual is also available in print form (Abrami et al., 2017). ABRA can also inform the teacher's decisions about the balance of instruction. Specifically, the assessment feature enables teachers to review student and class performance on instructional activities for any period of time. Reports on a student's performance in an activity produced within this feature, communicate individual students' and class learning needs in order for the teacher to focus on areas of instructional need.

Lastly, a Parent Module allows students' parents access to multimedia resources and tips on how to support the use of ABRA in the home.

Also embedded in the Learning Toolkit Plus, *READS* (Repository for E-Books and Digital Stories) is a searchable collection of multi-lingual stories available online. It has been developed to supplement the stories within ABRA to help develop students' fluency and comprehension skills. READS contains over 500 free stories, many available in several languages including English, French, and Kiswahili. The stories are geared primarily to emerging readers from K through Grade 3. To allow readers from different cultural backgrounds and instructional contexts to enjoy the stories, READS offers a variety of themes, genres, country of origins, etc. Teacher support materials such as ABRA lesson plans also employ READS books and stories to further improve students' fluency and comprehension skills. Figure 1 reflects the structure of the software used in 2015-2016: ABRACADABRA modules and READS Digital library.

Insert Figure 1 about here

2.2. Research design

This research was conducted in primary schools in Mombasa and Nairobi, Kenya. It unfolded in two phases: phase 1 took place in 2015 and followed by phase 2 in 2016. The study was designed as a two-group, non-equivalent, pre-test-post-test quasi-experiment. In both years, classroom teachers implemented the ABRA-READS intervention in their classrooms for several months (between May and September) -- primarily in Terms 2 and 3 of the 2015 and 2016 school years. Student reading achievement data was collected in the winter of 2015 and 2016 as a pre-test, prior to the ABRA-READS intervention, and again in the fall of 2015 and 2016 as a post-test. In both phases data collection was completed by the local team including ABRA project coordinators and ambassadors trained by the research team. The key difference between the two phases was that the treatment was targeting different age groups. In 2015, grade 1, 2, 3 students participated in the study while in 2016 grade 3 students only were targeted. Some of the students from the 2015 study also participated in the 2016 study. Unable to randomly assign teachers and their students to conditions, we relied on statistical means to deal with group nonequivalence.

2.3. Sample

In total, 48 teachers and their 1,899 students participated in both phases of the ABRA and READS research. It is the smaller student sample that provided data for the analyses (N=1,676). Some factors, such as turnover and absenteeism of students were accountable for the initial reduction in the sample size. However, the major factor in the reduction occurred as post-test data collection was limited to classes with at least medium implementation of ABRA and READS and their matching controls. This was especially indicative of phase 1 where two months of classroom instruction were impacted by teacher strikes.

Table 1 summarizes the information on students who participated in the ABRA and READS research by the project phase, treatment, grade and gender. In phase 1, the participants came from 22 classes (11 experimental, 11 control) whereas in phase 2, they were from 26 classes (16 experimental and 10 control classes). In both phases, to minimize the program spill-over effect experimental and control classes came from different schools. There were seven experimental and five control schools in 2015 and nine experimental and six control schools in 2016.

Insert Table 1 about here

We were able to extract some longitudinal data for phase-two experimental students in grade 3 classes. Specifically, we drew on the grade-one student data collected in 2014, the year when ABRA was piloted under the authentic conditions of Kenyan classroom use. After matching, the longitudinal data for 180 students from eight ABRA classes collected in 2014 (grade 1), and 2016 (grade 3) were available. However, only thirty students from one grade 2 class from this cohort participated in the 2015 data collection. Longitudinal data (2015 and 2016) are available for forty-six students from two grade 2 classes who joined the study in 2015. Table 2 reflects the fluctuations in the 2014 and 2016 longitudinal data.

Insert Table 2 about here

In both phases, the ABRA teacher sample included novice ABRA teachers and teachers who had experience with using ABRA in previous years. The split was as follows. In 2015 the group included four new ABRA teachers whereas in 2016 there were five. Seasoned ABRA teachers were seven and eleven respectively. In 2016, two new teachers joined the project later in the year to substitute the seasoned teachers who had retired. Thus, the balance of new and experienced teachers was seven and nine, respectively, in phase 2.

2.4. Intervention

A three-day initial training workshops was held for the ABRA teachers on how to use the software to teach literacy in both phases. Faithful to the model set in the 2013 pilot, it was the Kenya team (ABRA coordinators and ambassadors) who facilitated the ABRA and READS training of classroom teachers. ABRA ambassadors, seasoned master teachers some of whom had started using ABRA as early as 2012, actively participated in the initial training. The group included 7 ambassadors in phases 1 and 2 of the study. They also provided ongoing support to the assigned ABRA classroom teachers. The support system included weekly thematic planning sessions with teachers and regular classroom visits to support instruction. The planning sessions focused on the following aspects: integration of ABRA into instruction, alignment of ABRA with the Kenya curriculum, differentiated instruction, using ABRA in large classes and cooperative learning. Each session encouraged teacher reflections on their teaching experiences.

The ABRA ambassadors and local coordinators were able to manage the training and follow-up support with minimal guidance from the research team from Canada. In addition, the ABRA teachers were provided with teaching materials including an ABRA curriculum developed expressly to align the use of the tool with the Kenyan English Language requirements for primary grades 1, 2 and 3. The materials also included lesson plans, classroom activities, and job aids for teachers. To help teachers address the issue of managing exceptionally large classes and ensure adequate gender balancing, ABRA teachers were offered support materials promoting grouping strategies based on the theory and evidence of cooperative learning (Abrami et al., 1995). The support materials also included refined lesson plans from the previous years. The use of these materials was suggested rather than prescribed and their use was left to each teacher's discretion. Multimedia scaffolding and support for teachers and students embedded in ABRA were also available. The READS stories were offered in both phases to provide students with additional reading sources in English and Kiswahili.

Technical support was a key to the viability of this project. A partner organization that provided reconditioned computers to schools and the local team worked together to ensure that the schools were outfitted with functioning computer labs and that ABRA was installed and internally networked in each participating school. To augment ABRA use, each teacher also received a laptop that she used for planning her classroom instruction. The formal commitment and contribution of schools to the multilevel support system was important. This included ensuring proper infrastructure in the school computer labs, installation of the software on the school server, and the provision of ongoing maintenance. In addition, the school administrators created schedules to maximize students' access to school labs and liberated teachers' time to attend training and planning meetings.

The length of the ABRA intervention varied from year to year but on average lasted for about 16 weeks between April and September (mainly term 2 of the school year). ABRA implementation fidelity requirements, which are set to ensure the optimal integration of the tool in teaching (for instance, Abrami , Borokhovski & Lysenko, 2015), also include time guidelines for student exposure to ABRA instruction. These guidelines recommend use of ABRA for about two hours per week per student for no less than 13 weeks.

2.5. Instruments

The *Group Reading Assessment and Diagnostic Evaluation*, GRADE (Williams, 2001) alternative forms of level 2 was used to measure students' reading outcomes in the fall and spring of both school years, before and after intervention. This set of measures for assessing reading skills and monitoring reading progress targets vocabulary, reading and listening comprehension skills. The Vocabulary subtest composed of word reading and word meaning scales assess the ability to both decode regularly spelled words and recognize sight words and to understand early-reading vocabulary. The Reading Comprehension subtest incorporates sentence and passage comprehension subscales measuring understanding of a) a sentence as a whole thought by using contextual cues, knowledge of grammar and vocabulary; and b) passages of different genres, on different topics and of different lengths by drawing on a variety of comprehension strategies such as questioning, clarifying, summarizing and predicting. The Listening Comprehension subtest measures linguistic comprehension without printed cues. The reported reliability coefficients for the total GRADE test scores are 0.90 and higher. Test-retest reliability ranges from 0.77 to 0.98. In addition, the end-of-year *national examination* results were used to assess the impacts of the intervention on student performance in reading and other subjects. These results included English and other core subject matters taught in English, including Social Studies, Mathematics, and Science.

A set of the researcher-developed instruments was used to capture information about English Language instruction and ABRA implementation as well as teacher-generated lesson plans. The *Literacy Instruction Questionnaire* (2011) elicits teacher reports on aspects of the instructional methods they used in their classroom including approaches to reading and comprehension instruction and use of technology. The *Literacy Classroom Observation Form* (2012) was used to collect additional data about classroom instruction including classroom environment, word-level and text-level activities as well as technology used as part of instruction; and details of collaborative work. A weekly submission of *Lesson Plans*, involving the integration of ABRA in language instruction, were requested from experimental teachers. ABRA-generated *Trace Data Reports* were retrieved from the ABRA database once a term to follow the dynamics of the tool use. These were only used to complement the implementation information collected by other instruments.

3.6. Analyses

After the GRADE student booklets had been scanned locally, the datafiles were forwarded to the research team for analyses. The data were merged to create the file appropriate for longitudinal analysis. The cases from the 2014 datafile were added manually as were the end-of-year national examinations scores. Standard data screening procedures completed in the SPSS suggested that there was no marked kurtosis or skew in the attainment data nor were any univariate outliers detected.

In the absence of random assignment, independent two-sample t-tests on all pre-test measures were run on the 2015 and 2016 datasets to empirically test for the initial difference between the control and experimental groups. The analysis of the 2015 data revealed no significant difference ($p > 0.05$) between the groups on the GRADE subtests. For the 2016 dataset, the difference was statistically significant between the two groups ($p < 0.01$). This came as no surprise because eight of the 11 classes in the experimental group had been exposed to some ABRA-READS usage in previous years. The distinction between the new and previous users of ABRA within the experimental group and the pretest difference between them and the control group made us rely on the repeated measures multivariate analysis of variance (RM MANOVA) for the main analysis of the 2016 datafile. To keep consistency, RM MANOVA was also applied to the 2015 data. The basic analytical two-way model included testing time (pretest-posttest) as the within-subject variable and treatment (ABRA -- no-ABRA) and gender as two between-subject factors. Additionally, the model was modified to include the variables unique to each phase of the project. Specifically, a grade level (grade 1, 2, 3) variable was included in the analysis of the 2015 data. Because the 2016 sample consisted of grade 3 students from classes either new to ABRA or with some previous exposure to it, in the additional analysis the dichotomous variable of treatment was turned into a three-level categorical variable with “no ABRA”, “new to ABRA”, and “previous ABRA”.

The analysis of covariance model was used for the four outcome variables of English, Math, Science and Social Studies to compare the ABRA-READS and control groups. Listening comprehension was the GRADE subscale used as a covariate in this ANCOVA model since the two groups differed minimally on it at the pretest in both phases.

3. Results

3.1. Student reading achievement

3.1.1. GRADE results

Phase 1 results collected in 2015 were analyzed by repeated measures MANOVA. The two-way model included testing time (pretest-posttest) as the within-subject variable and treatment (ABRA-READS - control), gender and grade level (1, 2, 3) as three between-subject factors. Student achievement data collected in study 1 are presented in Table 3 and include means and standard deviations on each of the GRADE subtests. Repeated Measures MANOVA Pillai's trace criterion indicates statistically significant difference between ABRA-READS and control students on a combined set of reading-related skills overtime -- $F(3, 686)= 31.93$, $p< .000$. Partial eta squared of 0.12 suggest an important difference between the groups on the combination of GRADE subtests. Univariate tests further indicate that the ABRA effect was significant on each of the three GRADE subtests including Vocabulary ($F(1, 688)=59.8$, $p< .000$; partial $\eta^2 =0.08$) Reading Comprehension ($F(1, 688)=40.33$, $p< .000$, partial $\eta^2 =0.06$) and Listening Comprehension ($F(1, 688)=38.6$, $p< .000$, partial $\eta^2 =0.05$).

The means and standard deviations summarized in Table 3 by GRADE subtests, time, treatment, gender and grade level, indicate that the reading improvements of ABRA students were significantly higher than those of control students whose overall scores remained by and large unchanged.

Insert Table 3 about here

In addition to the treatment effect, the other between-subject factors of grade and gender contribute to the difference between ABRA and control students in the overall reading gains over time, $F(3, 686)=5.66$, $p= .001$; partial $\eta^2 =0.02$ and $F(6, 1372)=11.47$, $p< .000$; partial $\eta^2 =0.05$

respectively. The results suggest that on the three GRADE subtests of Vocabulary, Reading Comprehension and Listening Comprehension ABRA students of both genders gained more than their control peers. At the same time in ABRA classes, girls' gains were higher than those of boys. Grade one, two and three ABRA students consistently outperformed control students from the respective grades on the three GRADE subtests. However, on the Vocabulary subtest more important gains were demonstrated by grade one and two ABRA students whereas second- and third-graders in ABRA classes gained more in Reading Comprehension than ABRA grade-one students.

Phase 2 GRADE scores collected in 2016 were also analyzed with the Repeated Measures MANOVA test. The descriptive statistics by GRADE subtests for the total sample and sub-samples by condition, gender and prior exposure to ABRA-READS and baseline reading ability are summarized in table 4. The analyses revealed a statistically significant difference between grade 3 ABRA-READS and control students on a combined set of reading-related skills overtime. Pillai's trace criterion was as follows $F(4, 965)= 4.56$, $p< .001$, with a small effect size of 0.02 measured by partial η^2. Univariate tests further indicated that ABRA's effect was significant for the Reading Comprehension subtest ($F(1, 968)=9.59$, $p=.002$, partial $\eta^2 =0.01$) only. When added to the analytical model, student gender did not account significantly ($p=.67$) for the differences between ABRA-READS and control groups suggesting that grade-three boys and girls learning gains were similar in both conditions.

Since by the end of phase 2, some classes were exposed to ABRA-READS longer than one year, we ran an additional Repeated Measures MANOVA analysis of phase 2 GRADE data using a three-level categorical variable ("no ABRA", "new to ABRA", "previous ABRA") as a between-subject factor. The results show that the amount of exposure to the software contributed to the difference between the groups in GRADE scores ($F(8, 1934)= 2.63$, $p=.007$ measured by Pillai's trace criterion). Univariate tests revealed that it is the subtests of Vocabulary and Reading Comprehension subtests where the difference was statistically significant -- $F(2, 969)= 3.26$, $p=.003$ and $F(2, 969)= 4.34$, $p=.013$ respectively. On Reading Comprehension grade 3 students from classes exposed to ABRA-READS longer than one year gained significantly more than their peers in classes new to ABRA-READS ($p_{vocabulary}<.000$; $p_{reading\ comprehension}<.000$) and obviously, the control students. Further, the students with prior exposure to ABRA-READS continued to maintain their superiority over the other two groups. Yet, it was the new students who demonstrated the most consistent pattern of improvement in the key reading skills.

Insert Table 4 about here

A previous study (Abrami et al., 2016) indicated that ABRA-READS effects may vary as a function of student pretest reading ability differences. Therefore, some additional analyses were run to explore the benefits of using the software for grade-three low readers. Thirty-three percent of students from the phase 2 sample obtained scores less than 102 points on the GRADE Total test. As before, RM MANOVA was run to compare the change in reading scores of low readers in ABRA-READS (N=100) and control (N=216) groups. The results reveal statistically significant differences between low readers from ABRA and control groups on a set of reading-associated measures – $F(3, 312)=6.24$, $p=.000$, with a medium effect size of 0.06 measured by partial η^2 . Univariate tests indicated group differences on all GRADE subtests but reaching the threshold of statistical significance for the Reading Comprehension subscale only ($F(1, 314)=16.39$, $p=.000$; partial $\eta^2=0.05$).

3.1.2. Kenya exams

To complement the analysis of students' reading scores measured on a standardized test, we used the end of the year national exams in English and in the other core subject matters taught in English, including Social Studies, Mathematics, and Science that the participating schools provided both in 2015 and 2016. The exam scores were available for the following number of students in both samples: 464 students in phase 1 (N_{ABRA}=149; $N_{control}$=315) and 904 students in phase 2 (N_{ABRA}=460; $N_{control}$=444). It is important to note that the exam scores are positively and significantly correlated with GRADE test scores. Specifically, in 2015 and 2016 the correlation coefficients ranged between .60 and .70 (GRADE Total and English); .72 and .52 (GRADE Total and Social Sciences); .73 and .69 (GRADE Total and Science); and .40 and .57 (GRADE Total and Math).

Since Listening comprehension was the only GRADE subscale on which the baseline difference between ABRA-READS and control groups was minimal in the two phases, we used it as a covariate in the ANCOVA model for the four outcome variables of English, Math, Science and Social Studies. The analyses revealed statistically significant ($p< .000$) difference between the experimental students and their peers from the control group on all four key subject matters consistently favouring the ABRA-READS students in both phases of the project. Table 5 summarizes the ANCOVA descriptive statistics.

Insert Table 5 about here

3.1.3. A longitudinal view

The 2016 sample was heterogeneous including grade 3 students from the classes exposed to ABRA for one, two or three years. The important student turnover, absenteeism rates and variations in the names used to identify students at different times of testing, allowed to follow the dynamics of reading achievement results over the years for only a small group of 226 grade-three students from 10 ABRA classes. For the remaining 112 students enrolled in these 10 classes only one-year data collected in 2016 were available. The GRADE scores of 180 students from eight classes who had been initially exposed to ABRA in 2014 were matched with the 2015 and 2016 results when these students were in grade 2 and 3 respectively. Both pre and post-test GRADE scores were available for a handful of students (N=46) from two classes who started using ABRA in 2015 when they were in grade 2 and continued to 2016 when they were in grade 3. Finally, 160 third-graders from five classes had their first encounter with ABRA in 2016 only. Unfortunately, no longitudinal GRADE scores for control schools were available for comparison. Table 6 below summarizes the available longitudinal data.

Insert Table 6 about here

A visual representation of the longitudinal data (Figure 2) suggests a few patterns in the dynamics of reading achievement of a handful of students who learnt with some ABRA-READS over a few years.

Insert Figure 2 about here

The lines suggest incremental growth per year for the students in the three groups. It seems that the length of exposure matters –longer use of the tools allows the students both to improve at a higher rate and to maintain their superiority. The grade level at which the students start learning with ABRA-READS may also matter implying greater gains for those who started using it in earlier grades rather than in grade 3.

3.2. Literacy instruction

In both phases the instruction-related data were collected by means of surveys, reports, observations, lesson plans and ABRA trace data reports. These data were not as complete as hoped for but still provided some useful information about the strategies used to teach literacy to primary students. Experimental teachers' self-reports indicated that they taught phonics, fluency, vocabulary and comprehension to their students more often than their colleagues in control classes who relied on the traditional frontal teaching approach. Over years the ABRA-READS teachers shifted towards a more balanced focus on the key literacy components than the control teachers. However, teaching reading comprehension strategies continued to be a lesser priority for them whereas fluency activities were taught most frequently and often independent of the student grade level. Classroom observations and trace data revealed a list of activities that the students were engaged in most often. These included ABRA-based word-level activities such as decoding, blending and segmenting. There was more variation in the text level activities where fluency activities, such as individual student reading to the teacher, choral reading, group reading, and ABRA tracking dominated. The ABRA comprehension activities the students engaged in included vocabulary development, story elements and summarizing. Some group work was observed in ABRA-READS classes with little details about how this group work was structured. In the observed classes, students' engagement with the software was marked as quite high. This included students' enthusiasm about completing the ABRA activities, their capacity to effectively navigate the software and attend to the task when doing an ABRA activity, as well as being autonomous with little or no prompting from their teacher. Teachers' enthusiasm and engagement in using ABRA-READS was also noted. For instance, some teachers used every means possible to complete an ABRA lesson, even in the face of obstacles such as power failures or non-functioning computers. In some cases, teachers brought in their own laptops to ensure their ABRA lesson could be completed successfully. The observations indicated little variations in the instruction in terms of gender-sensitivity. Boys and girls were called upon or asked questions equally, groups were a mix of both genders, and ratings of male and female students' performance and behaviour did not differ.

Reporting from teachers and ambassadors offered some information about the effects of the model to support the ABRA-READS implementation. The initial 3-day interactive workshop was led by the local team of ambassadors and focused on content-specific teaching strategies with active participation from the teachers. Attendance and engagement in the workshops were high with the majority of teachers leaving with a rudimentary understanding of ABRA-READS. The provision of regular planning sessions and in-class support provided much needed additional coaching and modeling, along with an opportunity for teachers to share experiences and learn from each other. Collaborative lesson planning and feedback enabled teachers to reflect on their own growth and achievements in using the tools and improving their literacy instruction.

4. Discussion

This study features the instructional technology-based reading intervention implemented in Kenya primary classrooms, including a comparison group, testing students at the baseline and at the conclusion of the intervention with a standardized measure of reading achievement, targeting a range of early primary grades and accounting for gender effects. More strengths of this study include the integration of the research-based and evidence-proven set of literacy software into authentic, unscripted everyday literacy instruction and the length of the projects that unfolded in two installments. The weaknesses of this research relate mostly to the research design and quality of the data. We used a strong quasi-experimental design but not a true experiment and thus we needed to account for differences among the groups. Incomplete and missing data also reduced our capacity to build a more comprehensive picture of the use of the software and how this links to primary students' reading gains growth overtime. Strong cultural norms may have resulted in the "courtesy-biased" data, responses that participants thought the researchers wanted to read or hear.

The authenticity aspect of this study deserves special attention. Much of the current scientific evidence on effective instructional uses of computers comes from efficacy trials, which suggests that the instruction is most successful when it taught by researchers or specially trained professionals rather than by regular classroom teachers (for instance, Okkinga et al., 2018). This study was able to capture the impact of ABRA-READS software use in the real-world conditions of Kenyan primary schools wherein there is a deficit of efficient technology infrastructure, classes are large and the ratio of students per computer is high. Notably, the intervention was undertaken by regular teachers within their regular unscripted English lessons in their regular classrooms and computer labs.

The overall effect of the intervention on students' reading were evident in both phases, and for different grades and reading levels, and both genders. Similar to the earlier findings (Abrami et al., 2016), the gains of the ABRA-READS students from grades 1 to 3 who participated in phase 1 were consistently and significantly higher than those of the control students on a range of reading skills including vocabulary, listening and reading comprehension. In phase 2 targeting grade 3 students, it was the reading comprehension that benefited the most from the ABRA-READS instruction suggesting that even though the software was not especially designed for older students, it produced more positive effects on students' reading ability than regular instruction based on recitation.

The gains of grade 3 low readers who learnt with ABRA-READS is an important finding as improving the literacy skills of the students, who are in greatest need of reading instruction is a key objective of any early literacy intervention. It implies that after implementing ABRA-READS in her class a teacher can predict that her weak reader can improve their reading comprehension skills by 21 percentile points. Further, as a result of exposure to ABRA and READS, the gap between the high and low performers diminished contrary to the well-known "Matthew's effect" (Stanovich, 2009) where the differences between high-ability and low-ability students increase when they progress through school.

In line with our previous research, ABRA-READS showed about equally effective for the students of both genders. In the two phases, girls and boys from the experimental classes showed enhanced performance on the standardized test compared to students from classes where teacher-directed and recitation instruction prevailed. By design ABRA and READS provide access to reading content and activities that equally advantage both boys and girls. The ABRA characters, their actions, and the activities that students engage in, help to dispel gender role stereotypes. Gender equality is a criterion to include stories in READS. It is applied to each story's content, including the plot and characters as well as the role models they may serve. In addition, the training and support materials offered to the teachers were meant to enhance their gender equality consciousness. For example, the cooperative learning support resources address the grouping of students to ensure adequate gender balancing and turn-taking.

The spill-over effects of the intervention to other subject areas merit some discussion. The analyses based on the curricular end-of-the-year examinations demonstrate consistently that in addition to English, ABRA-READS students outperformed their peers in control classes on the core subjects of Mathematics, Science and Social Studies. Indeed, this transfer of literacy skills is another important outcome that points towards the utility of the combined use of both software tools in promoting widespread effect on students' school success.

In sum, the impact of the intervention on students is evident. Its impact on classroom instruction remains subtle though. With teachers in the heart of the ABRA-READS implementation, the system of teacher training and support was tailored to address their needs in technical, pedagogical and content knowledge and skills and thus increase teachers' understanding of literacy and capacity to generate effective reading instruction. The framework we put in place echoes the model of effective professional development (for instance Darling-Hammond, Hyler & Gardner, 2017) in that it developed teaching strategies associated with curriculum content and technology, engaged teachers in active learning, provided collaborative spaces for them, offered models of effective and reflective classroom practices as well as coaching and support to address teacher individual needs. The training and support efforts were in the hands of the local team including expert teachers who had started teaching with ABRA-READS during the pilot stages. Putting the chore of support on this group of actors was a natural step since, by virtue of their experience with the software and proximity to teachers and students, they were in the position to offer professional development and pedagogical support to classroom teachers. Yet, improvements in literacy instruction were quite modest. The evidence revealed that the teachers developed a certain level of ease with both computers and software and accepted this technology into their classrooms. The teachers also seem to have somewhat advanced their teaching too as they were seen to use a more balanced approach in the teaching of key literacy sub-skills and accommodating their students' learning needs. Teacher enthusiasm towards teaching with ABRA and READS software, even when technical difficulties arose, was also noted.

It remains unclear whether the teachers were primarily interested in using tools that students could be assigned to work on independently. It might be that they opted in for using the software as a supplement that adds a learner-centered touch to their mainly teacher-centered instruction and thus felt they became more aligned with the current curricular discourse in Kenya without significantly altering the ways they teach. At the same time, educational change takes time and we realize that the minimal shifts of practice we observed might be indicative of an important first step forward on the way to deep, gradual and lasting improvement in instructional practice. Given the impending competency-based curricular reforms in Kenya, many changes in teaching practice are imminent. Since teachers are at the centre of any effort to produce positive change in student learning, further strengthening of the professional development aspect of an intervention is critical so that teachers can fully embrace the pedagogical sophistication offered by the learning technology. This means moving away from using drill and recitation methods of teaching, towards genuinely learner-centred approach where software is integrated in literacy instruction, not simply added on during a lab session.

If gradual, deep and lasting improvement in instructional practice is a sought for outcome then building up the capacity of schools to support teachers' efforts is a key (Coburn, 2003) where school community builds ownership of and takes responsibility for implementing an educational innovation (Pouezevara, Mekhael & Darcy, 2014). The team encouraged the transfer of ownership of the project over to schools by providing adequate training and support to address the needs of the school community, engaging the teachers (and others) in planning and reflecting on the implementation, and managing expectations. Another contribution to ownership comes from strong leadership, such as commitment and support exhibited by the head teachers. This translates into assigning a high priority to the use of ICTs in their school, encompassing the recurrent costs of the school's technology infrastructure into their own funding mechanisms to ensure its sustainable operation, wisely using existing technologies and access to the ICT support staff. However, to empower the schools for autonomous implementation, functional technology should be complemented with the school own pedagogical expertise to support implementation. Teachers are more likely to be able to maintain improvements overtime when these become the school priority and the activities of the teaching staff get aligned with it. Use of a school-based ambassador or lead teacher would result in the provision of timely support to teachers as opposed to the current system of ambassadors only serving at arms-length to the schools. These experts' main function then will shift to providing regular support and help to the school-based ambassadors.

The results of this study clearly indicates the need to continue to cultivating the "islands of innovation" whose foundation has been successfully laid. There is a bigger challenge ahead and this is to get beyond pockets of use towards a comprehensive innovation that encompasses at least half of the teaching and learning in the school and, most importantly, affects its entire culture. After all, our ultimate goal is to enable classroom practice to benefit from the material and intellectual inputs of the software long after the research activities and external assistance cease.

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References

Abrami, P. C., Borokhovski, E., & Lysenko, L. (2015). The effects of ABRACADABRA on reading outcomes: A meta-analysis of applied field research data. *Journal of Interactive Learning Research, 26*(5), 337-367.

Abrami, P.C, Chambers, B., Poulsen, C., De Simone, C., D'Apollonia, S., & Howden, J. (1995). *Classroom connections: Understanding and using cooperative learning*. Toronto: Harcourt Brace.

Abrami, P.C., Wade, A., Lysenko, L., Marsh, J. & Gioko, A. (2016). Using educational technology to develop early literacy skills in Sub-Saharan Africa. Education and Information Technologies. 19(4), http://dx.doi.org/10.1007/s10639-014-9362-4

Akyeampong, K., Pryor, J., Westbrook, J., & Lussier, K. (2012). *Teacher preparation and continuing professional development in Africa: Learning to teach early reading and mathematics*. Retrieved from https://www.sussex.ac.uk/webteam/gateway/file.php?name=tpasynthesis-report-july2011.pdf&site=320

Allington, R. (2011). What at-risk readers need. *Educational Leadership*, 68(6), 40-45.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in Technological Pedagogical Content Knowledge (TPCK). *Computers & Education*, 52 , 154-168. https://doi.org/10.1016/j.compedu.2008.07.006

Ball, J. (2010). *Enhancing learning of children from diverse language backgrounds: Mother tongue-based bilingual or multilingual education in the early years,* UNESCO. Retrieved from http://www.ecdip.org/docs/pdf/UNESCO%20Summary%202010-1.pdf.

Branum-Martin, L., Tao, S., & Garnatt, S. (2015). Bilingual phonological awareness: Reexamining the evidence for elations within and across languages. *Journal of Educational Psychology*, 107, 111-125. http://dx.doi.org/10.1037/a0037149

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*, 31-42. http://dx.doi.org/10.1037/0022-0663.96.1.31

Centre for the Study of Learning and Performance (CSLP). (2011). *Literacy Instruction Questionnaire (LIQ)* (Unpublished instrument). Montreal, QC: Centre for the Study of Learning and Performance. Retrieved from http://doe.concordia.ca/cslp/cslp_cms/sites/all/themes/jframe/downloads/PDF/LIQ_2011.pdf

Centre for the Study of Learning and Performance (CSLP). (2012). *Literacy classroom observation form* (Unpublished instrument). Montreal, QC: Centre for the Study of Learning and Performance.

Cheung, A. & Slavin, R. E. (2012). How features of educational technology programs affect student reading outcomes: A meta-analysis. *Educational Research Review*, *7*, 198-215. https://dx.doi.org/10.1016/j.bbr.2011.03.031

Clark, C., & De Zoysa, S. (2011). *Mapping the interrelationships of reading enjoyment, attitudes, behaviour and attainment: An exploratory investigation*. National Literacy Trust. Retrieved from https://files.eric.ed.gov/fulltext/ED541404.pdf

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. Educational Researcher, 32(6), 3-12. http://dx.doi.org/10.3102/0013189X032006003

Darling-Hammond, L., Hyler, M.E., Gardner, M. (2017, June). *Effective teacher professional* *development.* Palo Alto, CA: Learning Policy Institute. Retrieved from https://learningpolicyinstitute.org/product/teacher-prof-dev

Dubeck, M., & Jukes, M. C. & Okello G. (2012). Early primary literacy instruction in Kenya. *Comparative Education Review*, *56*(1), 48-68.

Deunk, M. I., Smale-Jacobse, A. E., de Boer, H., Doolaard, S., & Bosker, R. J. (2018). Effective differentiation practices: A systematic review and meta-analysis of studies on the cognitive effects of differentiation practices in primary education. *Educational Research Review, 24,* 24-35. https://doi.org/10.1016/j.edurev.2018.02.002

Evans, D. K., & Popova, A. (2016). What really works to improve learning in developing countries? An analysis of divergent findings in systematic reviews. *The World Bank Research Observer, 31*(2), 242-270.

Geva, E. (2006). Second-language oral proficiency and second-language literacy. In D. August & T. Shanahan (Eds.), *Developing literacy in second-language learners: Report of the National Literacy Panel on language-minority children and youth* (pp. 123–140). Mahwah, NJ: Lawrence Erlbaum

Guthrie, J.T., Hoa, A.L.W., Wigfield, A., Tonks, S.M., Humenick, N.M., & Littles,E. (2007). Reading motivation and reading comprehension growth in the later elementary years. *Contemporary Educational Psychology, 32*, 282–313. https://doi.org/10.1016/j.cedpsych.2006.05.004

Hall, K., & Harding, A. (2003). *A systematic review of effective literacy teaching in the 4 to 14 age range of mainstream schooling*. EPPI-Centre, Social Science Research Unit, Institute of Education, University of London.

Kim, Y.-S. G., Boyle, H. N., Zuilkowski, S. S., & Nakamura, P. (2016). *Landscape Report on Early Grade Literacy.* Washington, D.C.: USAID. Retrieved from https://allchildrenreading.org/wordpress/wp-content/uploads/2017/12/USAID-Landscape-Report-on-Early-Grade-Literacy.pdf

Koda, K., & Reddy, P. (2008). Cross-linguistic transfer in second language reading. *Language Teaching*, 41, 497-508. https://doi.org/10.1017/S0261444808005211

Lussier, K. (2015). Where were the teachers? Rethinking development actors' support to education in Sub-Saharan Africa. *International Journal of Foreign Studies, 8*(1), 3-22. https://doi.org/10.18327/ijfs.2015.06.8.3

Martinez, R., & Fernandez, A. (2010). *The social and economic impact of illiteracy: Analytical model and pilot study* (Report No. OREALC/2010/PI/H/12). Retrieved from: http://unesdoc.unesco.org/images/0019/001905/190571E.pdf

McEwan, P.J. (2015). Improving learning in primary schools of developing countries: A meta-analysis of randomized field experiments. *Review of Educational Research*, *85,* 353-394. http://dx.doi.org/10.3102/0034654314553127

National Reading Panel (NRP). (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction* (NIH Pub. No. 00-4754). Retrieved from http://www.nichd.nih.gov/publications/pubs/nrp/pages/report.aspx

Okkinga, M., van Steensel, R., van Gelderen, A. J., van Schooten, E., Sleegers, P. J., & Arends, L. R. (2018). Effectiveness of reading-strategy interventions in whole classrooms: a meta-analysis. *Educational Psychology Review (advanced online publication).* https://doi.org/10.1007/s10648-018-9445-7

Ono, Y., & Ferreira, J. (2010). A case study of continuing teacher professional development through lesson study in South Africa. *South African Journal of Education*, *30*(1), 59-74. Retrieved from http://www.ajol.info/index.php/saje/article/view/52602

Pressley, M. (2002). Comprehension strategy instruction: A turn-of-the-century status report. In C. Block & M. Pressley (Eds.), *Comprehension instruction: Research-based best practices* (pp. 11–27). New York: Guilford Press.

Pouezevara, S., Mekhael, S.W., & Darcy, N. (2014). Planning and evaluating ICT in education programs using the four dimensions of sustainability: A program evaluation from Egypt. *International Journal of Education and Development using Information and Communication Technology, 10*(2), 120-141. Retrieved from https://www.learntechlib.org/p/147458/

RAND Reading Study Group. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. Santa Monica, CA: RAND.

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Surkes, M. A., Wade, C. A., Woods, J. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education*, *72,* 271-291. http://dx.doi.org/10.1016/j.compedu.2013.11.002

Stanovich, K. E. (2009). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Journal of Education, 189*(1-2), 23-55. http://doi.org/10.1177/0022057409189001-204

UNESCO (2015). *Education for sustainable development: Learning objectives.* Retrieved from http://unesdoc.unesco.org/images/0024/002474/247444e.pdf

UNESCO Institute for Statistics (2017). *Fact sheet on youth and adult literacy 2017.* Retrieved from http://uis.unesco.org/sites/default/files/documents/fs45-literacy-rates-continue-rise-generation-to-next-en-2017_0.pdf

Wagner, D. A. (2014). *Mobiles for reading: A landscape research review*. JBS International` Inc and USAID. Retrieved from http://www.youblisher.com/p/1234054-Mobiles-for-Reading-A-Landscape-Research-Review/

Wagner, T. (2016). Technology for education in low-income countries: Supporting the UN Sustainable Development Goals. In: Lubin I. (eds) *ICT-supported innovations in small countries and developing regions. Educational communications and technology: Issues and innovations.* Springer, Cham. http://dx.doi.org/10.1007/978-3-319-67657-9_3

Westbrook, J., Durrani, N., Brown, R., Orr, D., Pryor, J., Boddy, J., & Salvi, F. (2013). *Pedagogy, curriculum, teaching practices and teacher education in developing countries (Education Rigorous Literature Review).* London: Department for International Development. Retrieved from https://eppi.ioe.ac.uk/cms/Portals/0/PDF%20reviews%20and%20summaries/Pedagogy%202013%20Westbrook%20report.pdf?ver=2014-04-24-121331-867

Williams, K. T. (2014). *Group Reading Assessment and Diagnostic Evaluation (GRADE*). Pearson Education Inc. Available at: http://www.pearsonassessments.com/learningassessments/products/100000646/group-reading- assessment-and-diagnostic-evaluation-grade-grade.html

Figure 1

ABRA modules (version 4.2) and READS

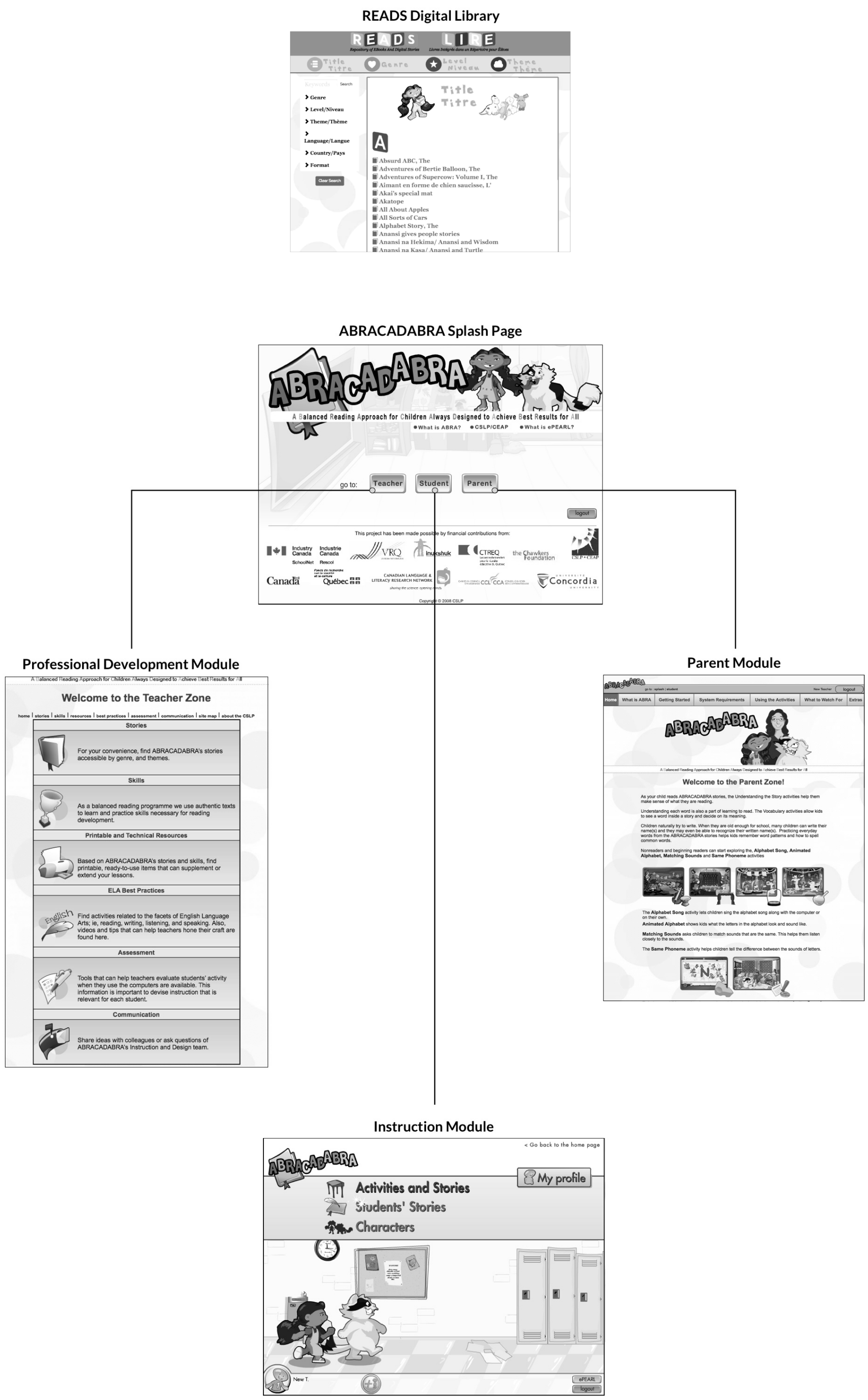

Figure 2

Dynamics of the mean GRADE scores.

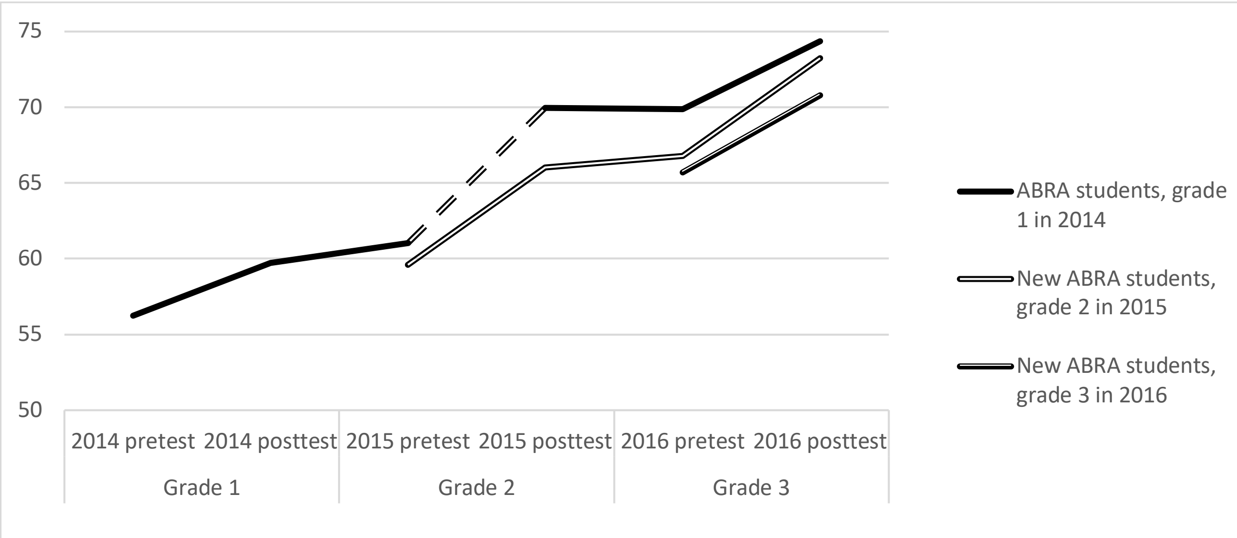

Table 1

Summary of the student sample in phases 1 and 2

		Phase 1, 2015		*Phase 2, 2016*	
		ABRA/READS	*control*	*ABRA/READS*	*Control*
Grade	*Grade 1*	*83*	*98*		
	Grade 2	*124*	*151*		
	Grade 3	*100*	*144*	*498*	*479*
Gender	*Girls*	*171*	*202*	*300*	*224*
	Boys	*136*	*191*	*198*	*250*
Total		*307*	*397*	*498*	*474*

Table 2

Summary of the subsamples for whom some longitudinal data exist

	2014, grade 1 (ABRA pilot)	2015, grade 2	2016, grade 3
Grade 1 in 2014	180	30	180
New, grade 2 in 2015		46	46

Table 3

Phase 1 means and standard deviations of GRADE subtest scores

	Vocabulary		Reading Comprehension		Listening Comprehension	
	Pre	Post	Pre	Post	Pre	Post
Total ABRA & READS group (N=307)	41.77*(10.9)*	44.42*(9.9)*	17.48*(7.75)*	22.56*(9.25)*	8.5*(2.78)*	10.91*(2.9)*
Total Control group (N=393)	42.49*(8.9)*	39.7*(9.3)*	15.85*(7.02)*	15.99*(6.95)*	8.94*(5.12)*	9.2*(2.9)*
ABRA & READS grade 1 students (N=83)	30.9*(11.71)*	34.22*(11.2)*	13.02*(4.53)*	13.36*(4.9)*	6.87*(2.3)*	9.16*(2.7)*
Control grade 1 students (N=98)	39.4*(9.25)*	35.2*(8.1)*	11.89*(4.13)*	12.13*(3.3)*	7.01*(5.6)*	7.26*(1.8)*
ABRA & READS grade 2 students (N=124)	43.46*(8.5)*	46.6(*6.45)*	16.14*(6.9)*	23.24*(7.07)*	8.57*(2.6)*	10.55*(2.8)*
Control grade 2 students (N=151)	41.31*(9.5)*	37.4*(9.5)*	16.15*(6.9)*	14.38*(5.09)*	8.42*(4.3)*	8.91*(2.82)*
ABRA & READS grade 3 students (N=100)	48.7*(3.17)*	50.2*(4.47)*	22.8*(7.76)*	29.39*(8.0)*	9.75*(2.7)*	12.8*(1.9)*
Control grade 3 students (N=144)	45.9*(6.9)*	45.2*(6.9)*	18.24*(7.6)*	20.31*(8.1)*	10.8*(5.03)*	10.74*(2.9)*
ABRA & READS male students (N=136)	40.87*(11.2)*	42.4*(11.05)*	17.27*(7.9)*	20.13*(9.04)*	8.39*(2.6)*	10.42*(2.8)*
Control male students (N=202)	41.98*(9.34)*	39.4*(9.31)*	15.23*(6.6)*	15.43*(6.6)*	8.5*(5.2)*	9.52*(3.06)*

ABRA & READS female students (N=171)	42.49*(10.6)*	46.03*(8.5)*	17.64*(7.7)*	24.5*(8.97)*	8.58*(2.6)*	11.3*(2.9)*
Control female students (N=191)	43.03*(8.6)*	40.06*(9.3)*	16.51*(7.4)*	16.58*(7.26)*	9.41*(5.04)*	8.8*(2.8)*

Table 4

Phase 2 means and standard deviations of GRADE subtest scores

	Vocabulary		Reading Comprehension		Listening Comprehension	
	Pre	Post	Pre	Post	Pre	Post
Total ABRA & READS group (N=498)	46.24 *(7.58)*	48.81*(5.76)*	23.76*(8.58)*	25.16*(8.62)*	10.97*(2.78)*	10.7*(2.75)*
Total control group (N=474)	41.23*(10.26)*	44.58*(8.66)*	19.96*(9.79)*	19.96*(9.57)*	10.13*(3.41)*	9.74*(3.44)*
Students in new ABRA & READS classes (N=160)	44.4*(7.47)*	47.81*(5.86)*	21.2*(7.39)*	22.98*(7.87)*	9.99*(2.43)*	10.36*(2.59)*
Students in classes with ABRA & READS prior exposure (N=338)	47.11*(7.49)*	49.34*(5.64)*	24.97*(8.86)*	26.3*(8.74)*	11.26*(2.83)*	11.07*(2.82)*
ABRA & READS male students (N=198)	46.19*(8.25)*	48.42*(6.79)*	22.68*(9.51)*	24.84*(9.37)*	10.97*(2.84)*	10.99*(2.80)*
Control male students (N=250)	41.82*(10.49)*	44.73*(9.35)*	20.61*(10.26)*	21.12*(10.1)*	10.57*(3.33)*	10.14*(3.59)*
ABRA & READS female students (N=300)	46.27*(7.12)*	49.07*(4.97)*	24.47*(7.86)*	25.37*(8.09)*	10.97*(2.75)*	10.51*(2.69)*
Control female students (N=224)	41.91*(9.72)*	45.61*(7.61)*	20.29*(9.21)*	20.53*(9.74)*	10.02*(3.38)*	9.73*(3.22)*
ABRA & READS low readers (N=100)	34.75*(7.09)*	43.34*(6.86)*	12.6*(3.25)*	17.11*(6.65)*	8.68*(2.86)*	9.2*(2.8)*
Control low readers (N=216)	32.53*(7.86)*	39.41*(9.57)*	12.59*(3.56)*	14.05*(5.05)*	8.17*(2.85)*	7.84 *(2.97)*

Table 5
Core exams results for ABRA and control classes (adjusted means, and standard error values)

	Phase 1		Phase 2	
Core subject exam	ABRA-READS students [1] (N= 149)	Control students [1] (N=315)	ABRA-READS students [2] (N= 460)	Control students [2] (N=444)
English	85.86*(1.34)*	74.03*(0.91)*	83.21*(0.69)*	77.43*(0.91)*
Mathematics	77.40*(1.58)*	68.31*(1.08)*	72.03*(0.89)*	61.33*(1.12)*
Science	86.39*(1.23)*	68.87*(0.84)*	77.66*(0.77)*	68.84*(1.07)*
Social Studies	82.25*(1.20)*	65.14*(0.83)*	77.15*(0.75)*	55.45*(0.84)*

[1]Adjusted means for post-test scores and standard error calculated in the model. GRADE pre-test covariate scores were evaluated at 8.85. Standard Error values are in parentheses.
[2]Adjusted means for post-test scores and standard error calculated in the model. GRADE Listening Comprehension pre-test covariate score was evaluated at 10.72. Standard Error values are in parentheses.

Table 6

Summary of the GRADE Total Test means and standard deviations

	Grade 1		Grade 2		Grade 3	
	2014 pretest	2014 posttest	2015 pretest	2015 posttest	2016 pretest	2016 posttest
ABRA students, grade 1 in 2014	56.24*(12.33)*	59.74*(12.14)*	61.03*(10.65)*	69.97*(11.97)*	69.88*(14.7)*	74.36*(12.09)*
New ABRA students, grade 2 in 2015			59.6*(9.64)*	69.06*(11.94)*	68.24*(9.59)*	73.94*(9.41)*
New ABRA students, grade 3 in 2016					65.7*(13.63)*	70.79*(12.46)*