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Using educational technology to develop early literacy skills in Sub-Saharan Africa

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Abstract The research explores the impact of interactive, multimedia literacy software (ABRA) on the reading skills of early elementary students in Kenya. Twelve grade two English teachers and their students from six schools were randomly divided in half: an experimental group (N=180) where ABRA was part of their English Language instruction and a control group (N=174) where regular instruction was used. After the pre-test student data were collected, a three-day initial training and planning session were held for the experimental teachers on how to use ABRA to teach literacy. Every week each experimental class was bussed to a computer lab with full access to ABRA for one 90-min lesson. Teacher support included the alignment of ABRA lesson plans with the Kenyan English Language norms, weekly web conferences with the trainer, as well as technical and pedagogical help from staff at the lab site. After the 13-week intervention, significant and substantial gains in reading comprehension were found for ABRA students as measured by GRADE, a standardized test of literacy. In addition, ABRA students outperformed their peers in control classes on the core end-of-year subject exams including English, Mathematics, Science and Social Studies.

Keywords Educational technology · Early literacy · Developing countries · Primary education

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1 Introduction

According to the United Nations Children's Fund (2012), nearly 90 % of the world's 127 million illiterate youth live in South Asia (65 million) and sub-Saharan Africa (47 million). In the least developed countries one quarter of young men and one third of young women, aged 15 to 24, are illiterate. In some of these countries, even students attending and completing primary school are unable to read and write basic sentences and are thus unprepared for further education. Literacy, in particular, is linked not only to success at school but also to subsequent employment and economic well-being: small gains in adult literacy rates being strongly correlated with large gains in national gross domestic product (Murray et al. 2009). International statistics show that Kenyan rates in English literacy, are well below the standards of developed countries (Knighton et al. 2010), with males having a higher literacy rate of 64.2 %, as compared to 58.9 % for females (Kenya Ministry of Planning and National Development 2007). In a recent Uwezo survey of literacy rates in Kenya (Mugo et al. 2012), researchers assessed 134,243 children in rural areas and found that nationally, 7 out of 10 children in class 3 are unable to do class 2 work and one out of five children in class 4 are unable to read this simple class 2 paragraph: "Sara has one brother. His name is Tom. Tom is 6 years old. He is in class one."

Low literacy rates in Kenya may be attributable to a number of environmental factors, but also to the lack of teacher awareness of successful literacy instruction approaches (Dubeck et al. 2012). According to Bunyi (2006) "the official position with regards to teaching-learning methodologies favours learner-centred activity based methodologies. However, a child in primary classes spends most of the time listening to the teachers and/or mindlessly repeating words or sentences after the teacher. Further, literacy development is not given adequate attention in teacher training programmes. For example, there is no special training for lower primary teachers who are expected to teach initial reading" (p. 8).

It is clear that literacy levels of Kenyan students need to be dramatically raised and that the teachers of those students would benefit from enhanced professional development that focuses on evidence-based strategies for literacy instruction. This paper summarizes the results of the project where ABRACADABRA (ABRA for short), evidence-based and evidence-proven multimedia software, was used to meet these dual challenges by equipping teachers with effective instructional strategies for literacy development of young students in Kenyan English Language classrooms. The following section provides rationale for implementing ABRA in teaching reading and specifies the research questions that the project pursued.

2 Study background

2.1 Effective literacy instruction

The strongest forms of reading research are those that are both well designed and that have been repeatedly replicated. The National Reading Panel report (NRP 2000) summarizes the best, consistent evidence on learning to read. In their findings the Panel notes that effective reading interventions must be comprehensive or balanced.

Truly balanced approaches emphasize reading skills such as: phonemic awareness – the ability to hear and manipulate individual sounds in spoken language; phonics – the ability to relate specific written letter(s) to specific sound(s) (grapheme–phoneme correspondence); fluency – the ability to read text effortlessly and expressively; and comprehension – the ability to understand and interpret text; and an emphasis on meta-cognition – ability to reflect and regulate knowledge construction. In addition, dozens of studies worldwide have shown these techniques to be effective in improving literacy when used as part of a classroom approach that also includes the fostering of: on-task activities, student self-regulation, connections across curricular themes, and communications between home and school (Hall and Harding 2003).

Therefore, we are in a position now where we know in principle what to do to enhance early literacy. For example, we know that effective preventative reading programmes in the early grades that involve structured phonics, word recognition, and letter–sound knowledge training that are over-learned and repeatedly connected to the end goal of text reading for meaning, are one of several important elements of balanced literacy approaches. The involvement of explicit attention to fluency and to a host of strategies for understanding and evaluating texts is also critical (e.g., Pressley 1998). We also know that teachers need support and expert professional development to overcome the challenges of teaching struggling readers (Chambers et al. 2001). Finally, we know generally that the effectiveness of classroom applications of educational software depend on careful attention to instructional design followed by professional development and follow-up support (Abrami et al. 2008; 2010; Meyer et al. 2010; Tamim et al. 2011; Gerard et al. 2011).

The next question is what prevents progress in literacy at a national and international level. One key problem is the lack of evidence-based practice in classrooms. One issue that prevents more widespread implementation of evidence-based programmes is that such programmes are frequently prohibitively expensive. Allington (2004), for example, argued in an influential paper in *Educational Leadership*, that the costs of current reading programmes in the United States (some $500,000 per typical school) effectively prevents full literacy for all from ever being achieved especially in countries like Kenya where cost issues are serious concerns. By providing ABRA software at no cost, by embedding some professional development and usage tracking within the tool, and by using local expertise for additional training and support, the costs of ABRA dramatically lessen the expense of implementing an evidence-based reading programme in developing countries like Kenya.

2.2 ABRA

ABRACADABRA (A Balanced Reading Approach for Children And Designed to Achieve Best Results for All) is evidence-based educational software, available to educators without charge. It is part of the Learning Toolkit that also encompasses other learning software tools such as ePEARL (self-regulated electronic portfolio). ABRA provides a web-based environment of engaging interactive multimedia for learning, accompanied by a wide range of support material. The content of ABRA learning activities is derived directly from systematic reviews of evidence about what works in reading and spelling (NRP 2000). Moreover, the embedded activities provide guidance for teachers in support of their transition from purely drill and recitation methods of

teaching (Arnold and Bartlett 2010) towards an approach that focuses on student comprehension of written and oral English. ABRA's division into essential skills for reading proficiency (most of which have various levels of difficulty allowing for differentiated instruction) ensures that teachers provide students with all the building blocks necessary for success. There is also a plethora of print-based materials and a large collection of 15 additional student-generated stories, helping to ensure usability and student engagement across a range of contexts and with a diverse collection of learners.

As Fig. 1 shows, in its current iteration ABRA consists of a: 1) Student Module offering 32 alphabetic, fluency, comprehension and writing instructional activities, many at different levels of difficulty and complexity; 21 stories of various genres linked to the activities; and 15 stories written by students each narrated by a Canadian, Australian and a Kenyan; 2) Teacher Module consolidating professional development material such as explanations, lesson plans, embedded video teaching vignettes, and printable resource materials, as well as access to a wiki encouraging teachers and other professionals to share strategies on literacy development and an assessment reporting feature where teachers can review student and class performance on instructional activities for a period of time; and 3) Parent Module allowing access to multimedia resources and tips on how to support the use of ABRA in the home.

The pedagogical underpinnings of the software are based on the evidence that successful reading requires active development of decoding skills, vocabulary and comprehension as well as learning specific strategies of reading (e.g. NRP 2000). Further, replicating the approach offered in programs of Balanced Literacy and defined as the "radical middle" by Jeanne Chall (1983) and described by Marilyn Jager Adams (1990), ABRA emphasizes a harmonious balance between code-emphasis and a literature-rich context. To reflect this approach, the ABRA instructional activities are designed within the context of story texts and vice versa. Moreover it allows children to pursue reading by applying a large repertoire of strategies that can be readily accessed when meaning breaks down (Pressley 2002).

The tool is a collection of pedagogical resources that teachers can use when, how, and with whom they see fit. The flexible and modular design of the ABRA software enables teachers to access and re-use the instructional components based on their teaching preferences and the needs of their students. Moreover the tool is neither linear in use nor prescriptive of a single approach or method of teaching students to read. Teachers can target specific skills for instruction as well as guide their class or individual students from basic sound and letter identification to complex tasks such as spelling, comprehension, and individual responses to various stories.

ABRA also offers embedded just-in-time multimedia for professional development and virtual tutorials to help teachers and students start using the tools appropriately and immediately. This embedded support helps ensure the tool and its underlying curricular and pedagogical principles and features are used properly.

2.3 Supporting research

To date there are more than a dozen studies exploring the impacts of ABRA on various facets of children's reading skills. Two of these studies are longitudinal, randomized controlled field trials, one conducted across Canada (Savage et al. 2013) and the second

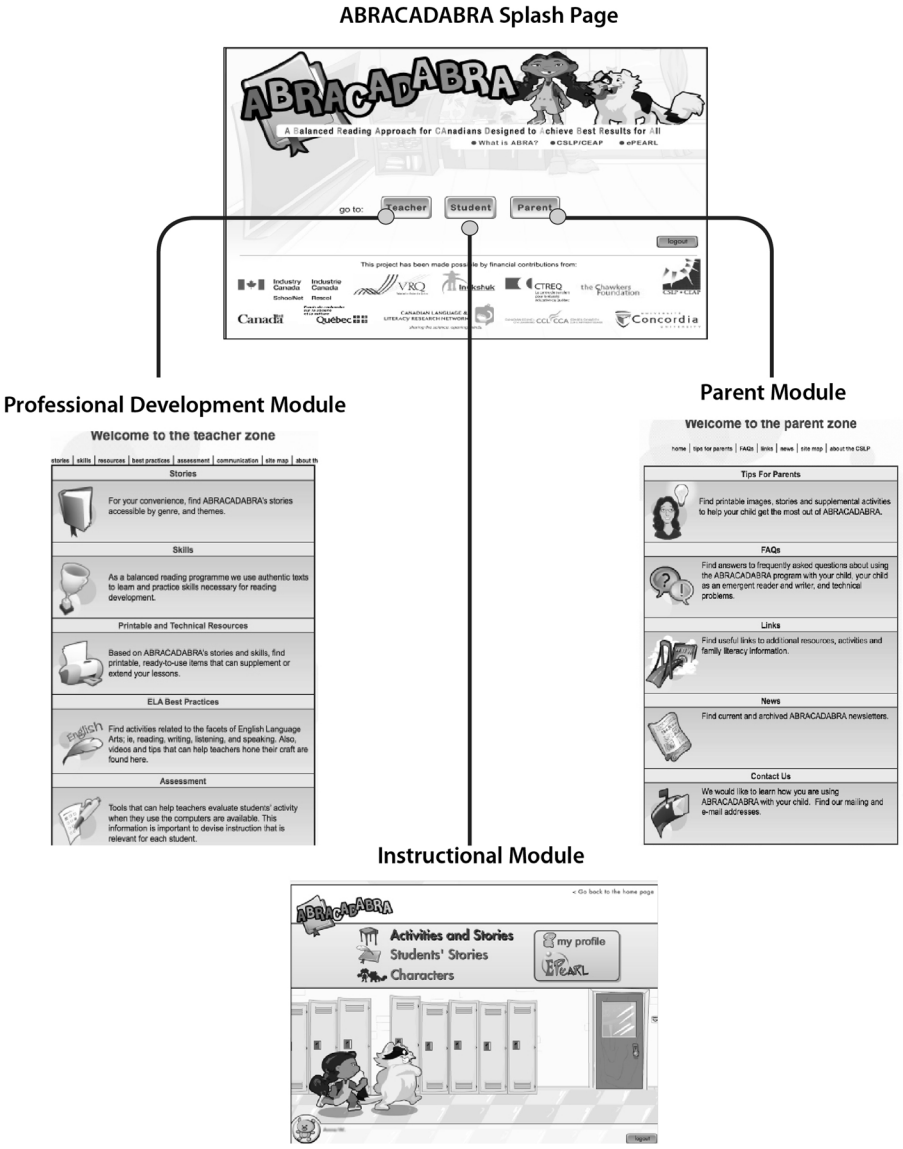

Fig. 1 ABRA features (CSLP 2012b, design by V. Pillay.)

conducted in remote and rural areas of Australia (Wolgemuth et al. 2013). The collected evidence demonstrates the effectiveness of the tool. ABRA aids young students with letter-sound knowledge, phonological blending, listening comprehension and reading comprehension (Savage, Abrami, Hipps and Deault 2009; Di Stasio et al. 2012; Savage et al. 2013). ABRA has also shown positive results in different populations: children with poor attention (Deault et al. 2009), and low socioeconomic pre-reading students in transition level classrooms (Comaskey et al. 2009).

It is important to emphasize that ABRA demonstrated its positive potential in a developing educational context experiencing challenges similar to those in Kenya. In

2009, ABRA was used in several Australian Northern Territory primary schools where the literacy outcomes of indigenous and non-indigenous students were evaluated (Wolgemuth et al. 2011, 2013). Student and teacher absenteeism and a shortage of teachers with the appropriate qualifications, skills and experience describe the conditions of the schools in the Northern Territory of Australia. The use of ABRA proved beneficial as results revealed both indigenous and non-indigenous students who received ABRA instruction had significantly higher reading scores than their control group peers, with a large effect size for this difference (eta squared=0.14).

The use of ABRA in Kenya and other developing countries fits well with many of the recommendations from the Brookings Institute (Perlman Robinson 2011), including "the need to build foundational skills in literacy and numeracy in the lower primary grades" (p.23) and the need to "prioritize literacy and numeracy in the lower primary grades" (p. 24). This is to be achieved through teacher professional development, increased time spent on reading, more appropriate reading material, and the creation of a culture of reading (including reading at home).

There is also much optimism regarding the potential of eLearning in Africa given recent improvements in the infrastructure (i.e. shared resource computing models, mobile phones and tablets, access to broadband connectivity etc.) (Isaacs and Hollow 2012), although Hennessy and Onguko (2009) argue that there is a significant need for research on how to effectively integrate technologies in Africa. This project is timely given the broad aim of the initiative is to positively influence the current discourse on teaching and learning within the Kenyan context. Our efforts also align with the Kenyan Government's Vision 2030 (www.vision2030.go.ke/) and the Ministry of Education's expressed interests and directives in both improving literacy and in increasing technology use in schools. The Kenya Institute of Curriculum Development has advocated technology integration through the development of portable digital content (www.kie.ac.ke/) For example, the Ministry's ICT initiative targets mainstreaming of information technology in 20,000 public primary schools, 6,000 public secondary schools, 22 provincial teacher training colleges, 2 diploma colleges and 10 model e-learning centres for Adult and Continuing Education. Furthermore, this project targets teachers' ICT skills as per the standards set by the UNESCO International Institute for Capacity Building in Africa (2012).

Our summary of systematic reviews of the uses of technology for learning (Tamim et al. 2011) found that teachers play an even greater role in students' technology-enhanced learning than the nature of the technology intervention itself. The effectiveness of the technology intervention depends on the teacher's goals, pedagogy, and content knowledge. Although more pre-service programmes prepare teachers to use technology-enhanced materials to enhance learning, in-service professional development programmes are the most common approach to introducing teachers to the goals and designs of technology interventions and to cultivating teachers' pedagogical content knowledge in this new domain (Mishra and Koehler 2006). In a recent review of technology integration and in-service support, Gerard et al. (2011) found that professional development programmes that engaged teachers in a comprehensive, active learning process and were sustained beyond 1 year were the most effective.

2.4 Project objectives

The specific purpose of the current study is to explore the feasibility and effectiveness of using ABRA, early literacy software and print-based materials, with emerging readers and their teachers in Mombasa, Kenya. From an examination of the Kenyan curriculum and discussions with the AKA staff and Mombasa schoolteachers we learned that there was a heavy emphasis in grade two on vocabulary including word meaning and reading. Therefore, we did not expect that the ABRA group would outperform the control group on these facets of reading. We did, however, expect enhanced performance of the ABRA students compared to control students on other essential reading skills.

In this project we attempted to answer the following questions:

- What is the effect of ABRA on students' reading skills?
- Does ABRA produce positive effects on boys' and girls' reading skills?
- Does ABRA produce positive effects on students of low reading ability?
- Does the effect of ABRA transfer to other school subjects?
- Does the use of ABRA help change the pedagogical approach to teaching literacy?

3 Methodology

3.1 Research design

A pre-test/post-test control group design with delayed treatment to the control participants was used in this study. Six pairs of volunteer teachers, with their classes matched on pre-test scores and other characteristics as closely as possible, were randomly assigned to either experimental or control conditions. Experimental teachers gave the ABRA intervention first while the control teachers used traditional methods of instruction. Control teachers and their students then used the software following post-testing.

3.1.1 Sample

Twelve grade two (standard) English teachers and their students (N=429) from six schools in the Mombasa area participated in the project. This group was randomly divided into two: six experimental teachers (those using ABRA as part of their English Language instruction in six classes comprising a total of 212 students) and six control teachers (those not using ABRA with their 217 students in six classes). From the total sample of 429 second-graders, 71 students did not write at least one of the tests for a variety of reasons. Specifically, 13 students were transferred to different classes during the year, 10 students were new to their classes and 47 did not attend lessons on the day of testing. Additionally, 4 students enrolled in the control classes (2 students from school 3 and 2 students from school 5) but mistakenly registered in the ABRA database as users, were also removed on the premise that their exposure to ABRA would have affected their post-test scores. These reductions resulted in usable data for 354 students (N_c=174 and N_e=180).

3.1.2 Intervention

In the spring of 2012 after the pre-test student data were collected, a three-day initial training workshop and several planning sessions were held for the experimental teachers explaining the use of ABRA to teach literacy. 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 standard 2 students. The materials also included lesson plans, classroom activities, and job aids for teachers. 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. To facilitate access to ABRA teaching materials, each experimental teacher was provided with a dedicated iBook where ABRA was locally installed. The project coordinator conducted web conferences on a weekly basis, both to support teachers and to provide them with a forum to discuss teaching issues using ABRA. Additionally, staff at the school training site provided help to the teachers by supporting them during the lab sessions and by providing feedback on ABRA lessons.

In total, the ABRA intervention lasted for 13 weeks from spring to fall during the second term. Every week, each experimental class was bussed to the school training site computer lab, which housed 21 desktop computers with full access to ABRA. The lesson for each class lasted up to 2 h per week. To increase the exposure time to the technology, teachers placed students in dyads or triads due to the large class sizes. About 2 weeks of the 13-week intervention were spent at the outset familiarizing students with computer learning environments in general and ABRA navigation in particular. Lab time was also occasionally lost due to late arrivals and the occasional technological glitches and there was a one-month delay mid-project due to a teacher strike.

3.2 Instruments

3.2.1 Student achievement measures

The *Group Reading Assessment and Diagnostic Evaluation*, GRADE Level 1 (Williams 2001) was used to measure the development of reading skills as it allows for testing a broad group of elementary students (from kindergarten to grade 2). Alternative forms of the test were administered to students in May 2012 (form B) to collect baseline data and in November 2012 (form A) to assess end-of-year reading achievement gains. As a standardized test designed to assess reading skills and to monitor reading progress, GRADE is a set of measures targeting vocabulary, reading and listening comprehension. Vocabulary subtest is composed of word reading and word meaning items. Word reading scale tests ability to both decode regularly spelled words and recognize sight words. Word meaning scale measures word decoding or sight-reading and understanding of early-reading vocabulary. Reading comprehension incorporates sentence and passage comprehension subscales. Sentence comprehension items measure understanding of a sentence as a whole thought by using contextual cues, knowledge of grammar and vocabulary. Passage comprehension items measure reading comprehension skills with multiple-choice questions drawing on a variety of comprehension strategies such as questioning, clarifying, summarizing and predicting

about passages of different genres, on different topics and of different lengths. A subtest of listening comprehension 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. Coefficients for alternate forms reliability range from 0.81 to 0.94, and a comparison of the means and standard deviations of both forms supports the equivalence of the forms.

Additionally, experimental and control teachers also provided their end-of-year examination results for students in English, and in other subject matters taught in English, including Social Studies, Mathematics, and Science.

3.2.2 Teacher and classroom measures

The *Literacy Instruction Questionnaire* (LIQ; Abrami et al. 2011) was used to collect information on various aspects of their English Language Arts teaching. Specifically, the questionnaire included three sections exploring reading and comprehension instruction, students' learning strategies, and the use of technology. Measured on a four-point frequency scale from "never" to "very frequently", 26 items asked about the activities teachers used to help students develop reading and comprehension skills. These activities include phonemic awareness and phonics (e.g., blending, segmenting, decoding), oral reading fluency (e.g., reading aloud, repeated oral reading), vocabulary (e.g., explaining word meaning), comprehension (e.g., question asking, story mapping), and writing (e.g., guided writing, editing) (NRP 2000). The questionnaire also asked teachers about engaging their students in self-regulated learning processes including goal setting, identifying strategies, self-monitoring, assessing outcomes, and adjusting their work. Nine items inquired about the time teachers spent using ABRA and/or other literacy software as well as the factors that might have affected their use of technology such as access to technology, insufficient knowledge of technology, and insufficient pedagogical knowledge. To capture possible changes in literacy instruction, the twelve teachers were asked to complete the questionnaire at both the pre- and post-tests in May and November of 2012 in sync with student data collection.

A *classroom observation form* (Centre for the Study of Learning and Performance 2012a) was used to collect additional data about the details of classroom instruction and includes four sections. The first section pertains to general classroom environment (including physical context and environment, classroom management, quality of teaching and learning and effects of technology). The second section focuses on English language activities such as word-level and text-level writing and extension activities and elicits specific information about the type of activity (e.g. segmenting, vocabulary development), time spent on each activity, and technology used as part of activity instruction. A separate section on classroom management draws attention to details of collaborative work such as types of collaboration, types of activities and time spent, and teachers' facilitation and instruction. Each item on the form is followed by a space where observers can leave their comments with regard to what they observed. Finally, the form includes a five-point scale to evaluate the overall classroom instruction. Each point on the scale is assigned a label containing a number of statements providing a description of a probable classroom situation. For instance point three is "Most students are attending to the given task. There is minimal or no off-task behaviour. The teacher is able to guide students through activities effectively."

Lesson plans involving the integration of ABRA into language instruction were requested from experimental teachers. The format of lesson plans was left to the teachers' discretion. Although thirteen lesson plans were expected from each teacher, the number of submissions varied from 1 to 11.

Videotaping of English language instruction was conducted during the 13-week long intervention in order to capture teachers' pedagogical techniques and students' learning experiences in both the ABRA and control groups. To ensure quality and usability of video materials, the video team was provided with the Videotaping User's Guide (Lysenko and Pillay 2012). The length of each video clip was set to 5 min. Teachers' instruction around ABRA or ABRA-related activities as well as students' interaction with the ABRA tool was focused on in the experimental ABRA classes.

Teacher final interviews were conducted shortly after the end of the intervention. The objective of these interviews was to learn about teachers': attitudes towards the use of the technology when teaching generally, and in the use of ABRA specifically; the factors that facilitated or impeded the use of ABRA; the extent to which the professional development material supported the use of ABRA; and the teachers' beliefs about effective pedagogy in the teaching of literacy. Some questions were drawn from the LIQ to determine the consistency of teacher replies.

3.3 Analyses

Before the main analyses, standard procedures were used to clean the data. At this stage, we detected systematic anomalies in the pre-test scores in one of the six experimental classrooms. In order to keep this classroom as part of the analysis, its pre-test data on all five GRADE subtests were imputed with estimates generated through a regression model, which slightly adjusted student scores.

For all GRADE achievement measures, analyses of variance (ANOVA) on simple difference scores (post-test minus pre-test) was used. Although the difference score has often been maligned as an unreliable index of change, statistical research (Zimmerman and Williams 1998; Thomas and Zumbo 2012) demonstrates a flaw in the traditional argument and suggests that the resulting non-use of difference score analysis is unwarranted.

In order to explore additional aspects of GRADE score changes between the groups, two additional analyses were run. The first one examined the changes in GRADE scores separately for boys (N=141) and girls (N=213). The second analysis assessed if the GRADE change scores varied with student pre-test reading scores. For this analysis, students' pre-test scores were divided into three equal-size groups. GRADE gain scores of low and high pre-test readers were then compared across those of ABRA and control groups.

Multivariate analysis of covariance was used to examine the differences between the groups on the end-of-term exam results in the following core subjects of the Kenyan curriculum: English, Math, Science and Social Studies. Mean scores of control and ABRA groups were compared after statistically adjusting for pre-test differences as measured by GRADE.

In addition to all the statistical analyses of significance, standardized effect sizes (i.e., Cohen's d) were calculated to estimate the magnitude of differences between the ABRA group and the control group.

4 Results

4.1 Student achievement

4.1.1 Overall GRADE results

To compare the reading skills of the experimental and control students at the outset of the ABRA intervention, independent two-sample t-tests of GRADE pre-test scores were completed. The results did not differ significantly ($p>.05$) on the five GRADE basic scales except in word reading where students' scores in the experimental group were significantly higher (t (1, 353) =3.82, $p<.00$) implying that both groups were mostly equivalent.

To answer the question if ABRA produced results on students' reading skills as measured by GRADE, we compared the test scores of control and ABRA students collected before and after the 13 weeks of ABRA intervention. A summary of the difference scores on all the subscales of GRADE test, is reported in Table 1. The results vary somewhat, mainly showing effects favouring the ABRA students.

The results indicate that on comprehension-related scores, students in ABRA classes improved their scores at a significantly higher rate than students in control classes. Specifically, they showed significantly larger improvements compared to their control counterparts in passage comprehension (F (1, 353) =12.26, $p<.00$) and listening

Table 1 GRADE means, standard deviations and gain scores

GRADE scales	ABRA means (N=180)			Control means (N=174)			Difference in gains between ABRA and control groups
	Post	Pre	Change	Post	Pre	Change	
Word reading (WR)	18.89	17.53	1.36	17.99	16.27	1.72	-0.36
Standard deviation	*2.08*	*3.18*	*3.12*	*3.18*	*4.08*	*3.45*	
Word meaning (WM)	24.32	23.60	0.72	23.74	23.29	0.44	0.28
Standard deviation	*3.46*	*5.21*	*4.82*	*4.00*	*4.62*	*3.99*	
Vocabulary composite (WR+WM)	43.21	41.13	2.08	41.72	39.56	2.16	-0.08
Standard deviation	*4.91*	*6.81*	*6.19*	*6.41*	*8.02*	*5.85*	
Sentence comprehension (SC)	12.63	12.17	0.46	11.94	12.17	-0.25	0.71
Standard deviation	*4.48*	*4.31*	*4.07*	*4.79*	*4.67*	*4.22*	
Passage comprehension (PC)	12.24	10.11	2.13	11.21	10.77	0.43	1.70
Standard deviation	*4.92*	*3.97*	*4.42*	*5.51*	*4.43*	*4.71*	
Reading comprehension composite (SC+PC)	24.87	22.28	2.59	23.13	22.95	0.18	2.41
Standard deviation	*8.73*	*7.21*	*6.96*	*9.52*	*8.14*	*7.16*	
Total (VC+RC)	68.08	63.41	4.67	64.87	62.51	2.36	2.31
Standard deviation	*12.42*	*12.17*	*10.00*	*14.53*	*14.87*	*9.90*	
Listening	13.63	11.84	1.79	12.76	12.61	0.15	1.64
Standard deviation	*2.66*	*3.43*	*2.67*	*3.35*	*3.56*	*3.03*	

comprehension assignments (F (1, 353) =29.04, $p<.00$). The effect sizes for these subscales are medium, that is 0.32 on the basic scores of passage comprehension and 0.54 on listening comprehension implying that the average student in the ABRA group improved by 13 and 21 percentile points respectively over his/her counterpart in the control group. In addition, there were significant gains in the reading comprehension composite and the total GRADE test score.

On the other hand, the analyses did not find statistically significant differences in change scores between the groups on vocabulary-related subscales including word reading and word meaning pertaining to student capacity to decode, recognize sight words and to understand their meaning as well as on the sentence comprehension subtest that provide contextual clues to derive the meaning of the unknown words. Both the ABRA and control students gained almost equally over the term. Given the emphasis placed on vocabulary in the classes of both groups, this is not an altogether surprising result.

4.2 Gender differences

In addition to the main analysis, we examined if ABRA effects differed for boys and girls. Table 2 consolidates the GRADE gain score differences for boys and girls in ABRA and control classes. The data show that boys in the ABRA group demonstrated higher gains than boys in the control group on all subtests except word reading. Moreover differences between them are statistically significant for comprehension-related scores of sentence (F(1, 140)=4.78, $p<0.05$) and passage comprehension

Table 2 GRADE means, standard deviations and gain scores for boys and girls in ABRA and control classes

GRADE scales	ABRA boys (N=73)	Control boys (N=68)	Mean difference for boys	ABRA girls (N=107)	Control Girls (N=106)	Mean difference for girls
Word reading (WR)	1.67	2.10	-0.43	1.15	1.47	-0.32
Standard deviation	*3.26*	*3.18*		*3.03*	*3.58*	
Word meaning (WM)	0.75	0.13	0.62	0.69	0.64	0.05
Standard deviation	*4.98*	*4.72*		*4.74*	*3.45*	
Vocabulary composite (WR+WM)	2.42	2.23	0.19	1.85	2.11	-0.26
Standard deviation	*6.46*	*6.38*		*6.02*	*5.50*	
Sentence comprehension (SC)	0.60	-0.63	1.23	0.36	-0.00	0.36
Standard deviation	*3.54*	*3.13*		*4.40*	*4.79*	
Passage comprehension (PC)	2.53	-0.38	2.91	1.85	0.95	0.9
Standard deviation	*4.23*	*3.90*		*4.53*	*5.11*	
Reading comprehension composite (SC+PC)	3.13	-1.06	4.19	2.22	0.97	1.25
Standard deviation	*6.75*	*4.98*		*7.11*	*8.18*	
Total (VC+RC)	5.56	1.22	4.34	4.07	3.08	0.99
Standard deviation	*10.44*	*9.26*		*9.69*	*10.26*	
Listening	1.55	0.04	1.51	1.95	0.21	1.74
Standard deviation	*2.83*	*3.01*		*2.55*	*3.06*	

(F(1, 140)=19.99, $p<.00$), total test (F(1, 140)=6.78, $p<.01$) and listening comprehension (F(1, 140)=9.34, $p<.00$). Similarly to the pattern of gains in boys' scores, the comparison of girls' gains scores in ABRA and control groups reveals higher gains for girls in ABRA classes on all basic tests except word reading. However, this difference was significant for thelistening comprehension subtest (F(1, 212)=20.06, $p<.00$) only and non-significant for the other four.

4.3 Differences in reading levels

Finally, we examined whether student reading levels at the pre-test were related to ABRA reading gains, in other words if ABRA had positive effects on students with low reading ability. Table 3 shows that in ABRA classes low readers' gains were slightly higher than high readers' gains on all GRADE subtests except Passage Comprehension. On the subtests of Word Meaning, Passage and Listening Comprehension, gains of low reading students in ABRA classes were higher than those of low readers in the control group. By improving low readers gains, ABRA was able to diminish the difference between high and low readers and at a higher rate than a regular reading instruction.

4.4 Exam results

To examine if ABRA effects are associated with students' learning in the core curriculum subjects, we used the results of end-of-term exams provided to us by

Table 3 GRADE gain scores for low and high readers in ABRA and control classes

GRADE scales	ABRA mean gains (*N*=118)			Control mean gains (*N*=119)		
	Low (*N*=58)	High (*N*=61)	Difference	Low (*N*=58)	High (*N*=61)	Difference
Word reading (WR)	3.22	0.28	2.94	3.64	0.26	3.38
Standard deviation	*3.99*	*2.31*		*3.87*	*2.75*	
Word meaning (WM)	3.34	- 0.65	3.99	2.15	-1.08	3.23
Standard deviation	7.01	2.38		4.72	3.69	
Vocabulary composite (WR+WM)	6.57	-0.36	6.93	5.80	-0.82	6.62
Standard deviation	*7.95*	*3.80*		*6.94*	*4.40*	
Sentence comprehension (SC)	0.52	-0.48	1	0.59	-1.09	1.68
Standard deviation	*4.30*	*3.51*		*3.90*	*3.38*	
Passage comprehension (PC)	1.57	1.65	-0.08	-0.11	0.14	-0.25
Standard deviation	*4.95*	*3.97*		*3.69*	*4.75*	
Reading comprehension composite (SC+PC)	2.10	1.17	0.93	0.52	-0.94	1.46
Standard deviation	*7.95*	*5.98*		*5.96*	*6.37*	
Total (VC+RC)	8.67	0.80	7.87	6.39	-1.76	8.15
Standard deviation	*12.29*	*7.57*		*9.81*	*9.39*	
Listening	2.09	1.55	0.54	0.12	0.09	0.03
Standard deviation	*3.46*	*1.84*		*3.68*	*2.49*	

Kenyan teachers. Because exam results from one of the control classes had not been furnished, this class and their matching ABRA class were dropped from the analyses (N=43). Table 4 shows the scores in English, Math, Science and Social Studies of control and ABRA students collected at the end of term three (November, 2012) after statistically adjusting these scores using the GRADE pre-test score as the covariate. The first analysis was performed for English exam scores. The second analysis was run for Math, Science and Social Studies in their totality.

The test for the effect of ABRA on English exam scores showed the difference between the groups was statistically significant (F (1, 336) =11.45, p<.001). The multivariate test for the main effect of ABRA on the three exams of Math, Science and Social Studies after having accounted for differences in pre-test GRADE scores was also significant (Pillai's trace =0.070, F (3,334) =8.13, p<.001).

The descriptive statistics summarized in Table 4 show that students in the ABRA group performed higher than control students on each of the four core exams. Although the indices of the magnitude of difference between the two groups were fairly modest across the exams, it is in English Language studies where an average ABRA student was able to improve by 11 percentile points as compared to his/her peer in the control group (Cohen's d =0.29).

4.5 ABRA implementation

This section presents analyses of the lesson plans, classroom observations, videotapes and final interviews.

4.5.1 Lesson plans

All of the 24 hand-written lesson plans received were transcribed and put into a standard template. The majority of lesson plans were submitted in the fall of 2012, between weeks 7 and 13 of the ABRA intervention. The lesson plans showed that teachers attempted to integrate activities targeting different literacy components

Table 4 Core exams means/adjusted mean and standard deviations/standard error for ABRA and control classes

Core subject exams	ABRA Means* (N=168)	Control Means* (N=173)
English	80.32 (80.39)	76.73 (76.65)
Standard deviation/error	*16.37* (*0.99*)	*20.71* (*0.98*)
Mathematics	68.10 (68.15)	65.82 (65.74)
Standard deviation/error	*19.57* (*1.29*)	*21.16* (*1.27*)
Science	77.68 (77.74)	74.71 (74.65)
Standard deviation/error	*19.09* (*1.37*)	*21.74* (*1.35*)
Social Studies	72.91 (72.99)	71.06 (71.01)
Standard deviation/error	*22.67* (*1.52*)	*22.12* (*1.49*)

* Adjusted means for post-test scores and standard error calculated in the model appear in parentheses. GRADE pre-test covariate scores model were evaluated at 64.32

including phonemic awareness, phonics, fluency, and comprehension. At the same time, these components were allotted different weights. For instance, activities built around text reading such as tracking were most frequently included in teacher lesson plans. These activities were followed in frequency of use by alphabetics and writing-related activities including spelling words and sentences. Among activities targeting comprehension teachers preferred vocabulary work. ABRA extension activities planned by teachers pertained to vocabulary development such as reporting new words learned in ABRA activities and using these words in writing sentences; writing sentences from stories; and finishing sentence starters. One teacher planned an ABRA story retelling activity; another one planned on using ePEARL's (electronic portfolio) recording feature to record the students' reading ABRA texts and writing their accounts of these texts in ePEARL's creation section.

4.5.2 Observations

Teachers were observed twice from late October to early November. The observation reports suggest that teachers, in addition to reading ABRA stories, used ABRA activities targeting alphabetics (same words, basic decoding, rhyming), vocabulary and comprehension. It is important to note that only one ABRA activity was ever the focus of the lesson and uniformly for all the students in that class. In large classes students were put to work in dyads and triads. Some student modeling to peers was reported by observers. It was also observed that boys' engagement with the tool was high. A few observations showed that students needed more guidance to complete an activity, and that students in one of the classes lacked syntactic background knowledge to successfully complete an activity.

4.5.3 Videotaped instruction

Each ABRA class was filmed up to four times whereas only two videos of two control classes were completed. The bulk of filming was done at the beginning of the intervention but a few videos were taken towards the end. The videos reveal that ABRA teachers and students grew increasingly comfortable with the technology and with the software. Students became at ease modeling ABRA behaviours to their classmates. Teachers developed autonomy teaching with ABRA and supporting their students. The teachers' capacity to use the tool to teach the English curriculum also improved: they were able to integrate ABRA in order to pursue the literacy objectives they had set. One of the teachers even experimented with the features of ePEARL, the tool she was barely acquainted with, in order to provide additional learning opportunities to her students.

The videos also show that within and beyond ABRA, language instruction was mostly teacher-centred. Whole class, uniform activities were given priority even though in ABRA classes the tool allowed for the differentiation of instruction to accommodate readers of different levels and ability. Teacher talking time took from 60 to 70 % of class time. Preference was given to choir work whereas students' individual responses were elicited less frequently. When responses were elicited, one-word responses were encouraged instead of complete sentences. Repetition after the teacher was a frequent technique. In order to support comprehension development, teachers preferred asking

general questions; for instance, "What did you read about yesterday?" or "What was the story about?" Special questions, focusing on the story elements, allowing students to reconstruct the story in detail, and using new vocabulary, were seldom asked.

4.5.4 Teacher self-reports (LIQ)

Pre- and post-data provided by eleven teachers (6 ABRA and 4 controls) were available for analysis. Two control teachers did not complete one of the 2 questionnaires. Twenty-six items of the Literacy Instruction Questionnaire (LIQ) were combined into four composite scores reflecting the four major literacy-related components including alphabetics (n=5), fluency (n=5), comprehension (n=11) and writing (n=5). At the baseline, the literacy instruction practices of experimental and control teachers were similar . On average, they reported having taught the four components occasionally and not used technology as part of their classroom practice. At the post-test, ABRA teachers reported higher frequencies of teaching all literacy components and using computers for English Language instruction than their control counterparts. Yet, this difference between ABRA and control teachers was significant in self-reported instruction of writing ($t(1,10)=2.48$, $p<.05$) and teaching with computers ($t(1,10)=2.39$, $p<.05$).

4.5.5 Teacher final interviews

Interviews were conducted with the six experimental ABRA teachers after the intervention had been completed. The teachers reported a number of positive shifts in regard to their comfort with computer technology, its pedagogical integration for curricular purposes and overall literacy instruction.

Although there were varying degrees of ICT literacy held by the teachers prior to beginning this project–with novice through to advanced users–all teachers stated their experience using ABRA positively impacted on their comfort level using the technology. Furthermore, all teachers expressed enthusiasm when asked if they would feel comfortable continuing to use the technology in their classroom. All teachers exhibited a positive shift in their attitudes towards using computers to teach literacy, as they saw a marked improvement in student achievement, especially with the slow leaners, increases in student motivation and engagement, and greater facility with classroom management. One of them commented: "*Next year my teaching will change. I used to look at non-readers negatively and felt I was wasting my time…. But now I realize that every student is reachable*, *you just need the right tools*." All teachers expressed a positive shift in their own teaching of English Language Arts due to a greater awareness of the need to instruct on the different components of emerging literacy including alphabetics, fluency, comprehension, and writing. The majority of teachers reported having used a dedicated iBook in their classroom for remediation, and as a complement to the lab sessions. For the most part, low ability students would use the computer prior to school, during breaks, or after school. All the teachers used didactic materials in the Teacher module, accessible from the dedicated iBook, when preparing lesson plans. Support materials such as the Teacher Guide were used moderately. The extent to which the print-based ABRA material was used in the classroom varied with the majority of the teachers using the worksheets to complement written work.

The interviews exposed a few challenges that ABRA teachers faced during implementation. The greatest challenge using ABRA in the lab related to technical issues, such as lack of availability of headphones or non-functioning computers. The teachers reported the need for further support in the lab, and more time assigned to using ABRA. At the interview some teachers were unable to accurately describe the key components of literacy implying their need of further training in effective methods of teaching reading.

5 Discussion

The objective of the project aligns with the Kenyan Ministry of Education's Vision 2030 expressed interests and directives to both improve literacy and increase technology use in schools. In order to verify the feasibility and effectiveness of using ABRA in different teaching contexts within Mombasa, Kenya, a rigorous, small-scale study was conducted as a precursor to a large scale, multi-year project. This section includes a set of inferences drawn from the student and teacher data. It also attempts to identify gaps and formulate recommendations for the future.

The reading achievement scores as measured on the standardised test show that after only 13 weeks of ABRA exposure, students in the six experimental classes improved more than students in the six control classes. Significantly greater gains were achieved in comprehension-related skills, including reading and listening comprehension.

Both experimental and control students gained equally in vocabulary-related skills such as decoding and sight-reading. An explanation we favour relates to the emphasis in the Kenyan curriculum on this aspect of reading. However, the failure of the ABRA students not to outperform the control students may indicate that the experimental teachers spent less time on certain alphabetic activities in ABRA. Otherwise, it may be that introducing ABRA earlier than the second term of grade two may be justified.

The reading achievement results also show that both boys and girls using ABRA outperformed control students, although boys benefited the most from ABRA exposure. The gains for girls as well as boys are a welcome finding in African contexts where there is less emphasis on school success for females.

Otherwise, it was important to note that students with lower scores on the pre-test gained significantly due to ABRA use. Improving the literacy skills of these students is an important objective of any early literacy intervention.

The data along with teacher testimonials indicate that it was the low-reading students, those in the greatest need of reading instruction, who enjoyed the greatest gains as they moved through the 13 weeks of instruction with the ABRA software. In fact, as a result of exposure to ABRA the gap between the high and low performers in ABRA classes diminished contrary to the well-known "Matthew effect" where the differences between high-ability and low-ability students increase when they progress through the formal education system.

Interestingly, the ABRA intervention seems to have had positive effects in several subject areas. Specifically, analyses based on the curricular end-of-the-year examinations demonstrate that ABRA students outperformed their peers in control classes on the four core subjects including English, Mathematics, Science and Social Studies. Indeed, this transfer of literacy skills is an important outcome pointing towards the utility of ABRA as a tool that may offer widespread impact on students' school success.

The data from the teacher self-reports provide some detail about the literacy instruction that occurred in the experimental and control classes. ABRA teachers' responses to the survey and interview questions reveal some positive shifts in their literacy instruction. Specifically, throughout the two semesters, they allotted more time to teaching all the literacy components and their comfort level with teaching with computers significantly improved. Experimental and control teachers differed in their self-reporting of literacy instruction showing that the ABRA teachers integrated activities targeting their students' alphabetic skills, fluency, comprehension, and writing more frequently than their control counterparts. Statistically significant differences were indicated between the groups with respect to teachers' declared use of writing activities and computers.

The observation data and lesson plans showed that during the thirteen-week intervention, teachers developed a certain capacity in the integration of the ABRA software throughout the grade-two English Language curriculum. While there was a shift towards serving in new roles as facilitators of their students' learning, the period of time was rather short for them to turn away completely from a habitual teacher-directed method of literacy instruction.

A number of limitations need to be noted in the present research. One issue relates to a wide range in the chronological age of grade/standard two students participating in the study. The typical age varied between 7 and 9 years old, yet there was a number of itinerant students scattered through the classes who were 10 and older. The effects of these differences in age were probably modest: there was no significant difference between the intervention and control groups across the sample in chronological age. The results may be potentially limited by using a North American standardized measure of reading achievement that may lack cultural sensitivity to adequately capture the development of reading skills in Kenyan students. Although we assume that some test items may include cultural details that the students are unfamiliar with, we were not able to discriminate those. Neither were such test items reported by test administrators nor revealed by the statistical analysis as items consistently scored the lowest.

To conclude, we were able to enhance the reading performance of Kenyan youngsters on an internationally recognized, and well-validated literacy measure with only about two dozens hours of targeted exposure to ABRA in dyads and triads and some amount of additional in-class activity. At the same time, we facilitated what appear to be changes in teaching practices about effective reading instruction and demonstrated that students in large classes can be taught using technology integrated into the curriculum, promoting the development of an essential educational competency. The next step will be to explore the scale up of the ABRA intervention in a larger Kenyan context to obtain a clearer picture of the support that teachers need to encourage their use of effective reading instruction and high-level integration of ABRA in their authentic school environment. And we are eager to continue.

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