The Potential and Prerequisites of Effective Tablet Integration in Rural Kenya

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Practitioner notes

What is already known about this topic:

- A lack of funding, planning, and infrastructure hinder information and communication technology (ICT) integration.
- Procurement of educational technology has reduced digital divides, but learning divides persist in implementation.
- Insufficient teacher technology expertise and professional development constrain teacher’s effective use of educational technology in classrooms.

What this paper adds:

- This research goes beyond technical challenges to examine in-depth the instructional, cultural and institutional factors that influence effective ICT integration in low-resource contexts.
- We employ mixed methods—triangulating student assessment data with data from student surveys and focus groups, teacher interviews, and classroom observations—to identify how sociotechnical and sociocultural factors interact in ICT integration in ways that support or constrain student learning in low-resource contexts.

Implications for practice and/or policy:

- In low-resource contexts, providing even basic levels of infrastructure (e.g., a consistent power source) and access to technical expertise requires more creative and concerted efforts from school leadership and instructors, including supplemental program efforts such as tutorials and reading clubs outside of class to expand access to devices.
• In settings such as rural Kenya, the benefits of achieving one-to-one device access must be weighed against the potential advantages of alternative investments, such as expanding professional development on device integration.

• Increasing opportunities for peer-to-peer learning and exchange (among teachers and students) and building shared capacities for ICT integration can help reduce technical issues and lost instructional time.

• More attention is needed in ICT integration to sociocultural factors to ensure that classroom instructors’ attention is equitably distributed in ways that discourages in-class “tracking” and differential access to quality learning experiences, such as some teachers’ disregard of “slow learners” in the classroom.

Abstract

This study investigates sociotechnical and sociocultural factors in education technology integration that are associated with more effective and equitable technology use in low-resource settings. In the context of a one-to-one tablet initiative in rural Kenya, we explore how these factors constrain or support access to technology, instructor capacity, student engagement and student achievement, as well as their implications for reducing educational and digital divides. Using data from classroom observations, teacher interviews, student surveys and focus groups, and assessments of student academic performance, we generate evidence on the effectiveness of the tablet initiative in increasing student achievement, as well as the primary challenges to successful technology integration. Our findings contribute to the identification of prerequisites and supporting factors for successful educational technology integration, as well as policy levers and school-based strategies that are likely to increase equitable access to quality learning experiences in schools in low-resource contexts.
Introduction

In the face of an increasingly competitive, global knowledge economy, governments, schools, and non-governmental organizations are turning to information and communication technology (ICT) as a means to increase student engagement and learning. Policymakers also see ICT as a promising strategy for improving access to educational resources and enhancing teachers’ ability to meet diverse student needs, particularly in low-resource settings (Herodotou, 2018; Twining, Raffaghelli, Albion, & Knezek, 2013; Wong, Li, Choi, & Lee, 2008, Warschauer, Knobel, & Stone, 2004). Among these are policymakers in the Ministry of Education in Kenya, which rolled out the ICT Integration in Primary Education (or Digital Literacy) project as one of its flagship programs for improving teaching and learning in Kenya’s public primary schools. The project components include: improvements in ICT infrastructure and procurement of devices, development of digital content, and capacity building of the teachers.

Despite the promise and hype, the literature is rife with discussions of the challenges of integrating technology and ensuring equitable access across a broad range of educational contexts (Hohlfeld Ritzhaupt, Barron, & Kemker, 2008; Warschauer & Matuchniak, 2010). In this research, we delved deeply into one low-resource setting in rural Kenya, where public schools and a community-based, non-profit partners are collaborating in implementing a one-to-one tablet initiative in primary schools under the Digital Literacy project. The goals of this eReader (tablet) initiative, supported by the Lwala Community Alliance (LCA), include improving access to educational resources, enhancing classroom learning, and increasing student achievement for students in North Kamagambo, Kenya. Toward that end, the LCA designed and implemented a pilot program that provided eReaders equipped with course books and supplementary books to Class 6 teachers and students at three primary schools in this region. At
approximately five percent the cost of laptops, the tablets (eReaders) may not only be a more viable option in low-resource contexts, but they are also potentially more suitable for younger (primary school) learners (Herodotou, 2018; Goff, Maylahn, Oates, Oates, & Wujcik, 2015; Tamim, Borokhovski, Pickup, & Bernard, 2015).

Our study addressed the following key questions within this research context: (1) How, and to what extent, does tablet integration improve students’ educational opportunities in rural Kenya? (2) What are the primary challenges to successful technology integration in resource-constrained contexts? (3) What policy levers and school-based strategies are likely to improve equitable access to quality learning experiences and overcome persistent infrastructure challenges within this context?

**ICT integration in low-resource, educational contexts: theory and evidence**

In conceptualizing our investigation of factors critical to successful ICT integration in low-resource contexts and their implications for equity in opportunities for learning at the primary level, we draw on two theoretical frames: sociotechnical and sociocultural theory. Sociotechnical theory begins with human action and examines how it enacts structures embedded in the technology, positing that individuals and their social settings shape both understandings and use of educational technologies in recurring interactions (Orlikowski, 2000). Sociocultural theory similarly focuses on understanding student learning and development through their interactions in educational settings, but with a greater emphasis on social and cultural processes as central to how individuals participate in activities and “how they draw on artifacts, tools, and social others in learning” (Nasir & Hand, 2006: p. 450; Rogoff, 2003).

Sociotechnical theory, for example, argues that teacher and student use of technology will be strongly influenced by users' understandings of the properties and functionality of the tablets,
which are in turn affected by individual and shared experiences about what the tablets can do and other capacity factors in the educational setting (e.g., technology support, training, communications, etc.) (Woolgar, 1996; Orlikowski and Gash, 1994). From sociocultural theory, we draw in the view that cultural norms and conventions transacted by students and teachers in the classroom will likewise influence how students understand the properties of the tablets and whether and how they draw on other individuals and resources in the classroom to support their learning with them (Nasir & Hand, 2006). In addition, sociotechnical theory motivates us to examine how the ratio of students to tablets in the classroom enables student tablet use, while sociocultural theory may lead us to ask how in the face of higher than desired student-to-tablet ratios, cultural norms may affect student access to or interactions around shared devices. The fusing of sociotechnical and sociocultural perspectives also prompts us to consider not only how investments in teacher professional development help to build teacher instructional and technical capacities, but also whether cultural norms enhance or hinder how teacher capacities then translate into increases in student engagement and learning in the classroom.

In fact, while public and nonprofit funding for educational technology purchases has narrowed ICT disparities in primary schools, existing research confirms that a range of sociotechnical and sociocultural factors have the potential to contribute to (or reduce) ongoing inequities in the use of educational technology to support student learning (Hohlfeld et al., 2008; Warschauer & Matuchniak, 2010). For example, studies of ICT integration in low-resource settings have found more turnover and variability in teaching and administrative staff, which hinders planning for and implementation of educational technology in classrooms (Warschauer, Knobel, & Stone, 2004). And even when teachers have confidence in or experience with the technology being introduced, they may be challenged by disadvantages such as larger class sizes,
more students with limited technology experience, and inadequate pedagogical and other instructional supports (Warschauer, Knobel, & Stone, 2004; Darling-Aduna & Heinrich, 2018).

Some of the most common barriers to ICT integration identified in prior research in developing country contexts include insufficient teacher technology expertise, ineffective educational software, access issues, and lack of alignment with educational norms or expectations (Buabeng-Andoh, 2012; Pelgrum, 2001; Venezky, 2004). Mndzebel (2013) identified lack of funding, planning, and professional development as major obstacles to ICT implementation in Swaziland. Likewise, in Ghana, 85 percent of pre-service teachers reported that they lacked appropriate training to use ICT (Gyamfi, 2016). While lack of internet connectivity was observed as a limiting factor across continents, lack of reliable electricity also restricted the utility of technology in studies set in Africa (Kenya, South Africa) and Asia (Cambodia) (Richardson, 2011; Stols et al., 2015). Multiple studies have also shown that across contexts, access to technical support, professional development, and other forms of assistance such as student technical capacity expand technical expertise and technology use (Buabeng-Andoh, 2012; Pelgrum, 2001; Richardson, 2011; Stanhope & Corn, 2014; Venezky, 2004).

Through our theory-informed investigation and in-depth depiction of education technology integration in a rural, Kenyan community, we build on the contributions of prior research to identify some of the prerequisites for improving student outcomes through ICT integration in low-resource contexts, while drawing out new insights for educators and policy makers. Our study goes beyond the technical challenges of ICT integration to also examine the instructional, cultural and institutional factors that support or constrain the effectiveness of ICT integration in increasing student learning and engagement, formed through the analysis and triangulation of assessment data, student surveys and focus groups, teacher interviews, and
classroom observations. We begin by describing our research setting, samples, and intervention, study data and measures, and methods below.

**Study samples, data, and methods**

*Setting, samples, and intervention*

The eReader initiative was first implemented in North Kamagambo, Kenya in 2016, through a collaboration between the LCA and rural, government-funded primary schools in this region of Western Kenya. The eReaders were provided by Worldreader, an international provider of tablets to developing countries, and distributed by the LCA for teacher and student use in three primary schools in the region. To aid selection for participation in the pilot, the LCA Education Team categorized all 13 school in the region by their average scores on the 2014 Kenya Certificate for Primary Education (KCPE) test into three distinct achievement tiers (low, middle and high). A total of 10 primary schools in North Kamagambo subsequently submitted proposals to participate in the eReader initiative. The LCA Education Team then selected two proposals from each of the three pre-established achievement tiers, considering the schools’ commitment to working with LCA and the aim to choose one school from each sub-area to receive eReaders.

Because the selection of classrooms for distribution of the eReaders was made via the criteria discussed above (and not via random assignment), it is important to assess and compare the characteristics of the treatment and comparison groups and adjust for pre-treatment differences in estimating associations between the eReader program and student outcomes. Table 1 presents summary statistics and tests of statistical significance for differences between the characteristics of the treatment and comparison groups at baseline, including on pre-treatment academic assessments. The results show that students in classrooms receiving the eReaders
| Table 1: Baseline Characteristics of eReader Treatment and Comparison Groups, 2016 School Year |
|-------------------------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| | Treatment group | Comparison group | | | | | |
| | N (students) | Mean | Std. Dev. | N (students) | Mean | Std. Dev. | Mean difference (T-C) | p-value |
| **Baseline academic performance** | | | | | | | |
| % correct words: Kiswahili | 95 | 0.88 | 0.22 | 128 | 0.89 | 0.19 | -0.009 | 0.736 |
| % correct words: English | 95 | 0.51 | 0.25 | 128 | 0.51 | 0.21 | 0.006 | 0.841 |
| Kiswahili correct words per minute | 95 | 44.67 | 23.10 | 128 | 63.23 | 31.68 | **-18.565** | 0.000 |
| English correct words per minute | 84 | 68.74 | 22.19 | 119 | 95.98 | 33.92 | **-27.246** | 0.000 |
| Kiswahili comprehension | 95 | 2.40 | 1.88 | 128 | 3.18 | 2.04 | **-0.780** | 0.004 |
| English comprehension | 95 | 3.42 | 2.09 | 128 | 3.64 | 2.05 | 0.220 | 0.434 |
| Kiswahili comprehension (incorrect) | 95 | 3.79 | 2.16 | 128 | 3.38 | 2.06 | 0.407 | 0.155 |
| English comprehension (incorrect) | 95 | 2.77 | 1.95 | 128 | 2.87 | 1.96 | -0.099 | 0.710 |
| **Student characteristics (pre-treatment)** | | | | | | | |
| Parents are primary caregiver | 94 | 0.71 | 0.45 | 127 | 0.64 | 0.48 | 0.08 | 0.243 |
| Male | 94 | 0.50 | 0.50 | 127 | 0.54 | 0.50 | -0.04 | 0.526 |
| Age | 93 | 12.88 | 0.15 | 127 | 12.39 | 0.10 | **0.49** | 0.005 |
| Access to less than 5 books at school | 94 | 0.12 | 0.32 | 127 | 0.16 | 0.37 | -0.04 | 0.349 |
| Access to 5-10 books at school | 94 | 0.46 | 0.50 | 127 | 0.69 | 0.46 | **-0.23** | 0.000 |
| Access to more than 10 books at school | 94 | 0.43 | 0.50 | 127 | 0.15 | 0.36 | **0.28** | 0.000 |
| Less than 5 books at home | 93 | 0.37 | 0.48 | 128 | 0.69 | 0.47 | **-0.32** | 0.000 |
| Child: I read only when I have to | 95 | 0.51 | 0.50 | 128 | 0.29 | 0.46 | **0.22** | 0.000 |
| Caregiver rarely/never reads to child | 95 | 0.25 | 0.44 | 128 | 0.18 | 0.39 | 0.07 | 0.188 |
| Caregiver rarely/never checks schoolwork | 95 | 0.21 | 0.41 | 128 | 0.20 | 0.40 | 0.01 | 0.893 |

Note: The comparison group consists of students attending schools that volunteered for the eReader initiative but were not selected to implement it.
scored significantly lower on the three measures of academic performance (before the start of the 2016 school year): oral reading fluency in Kiswahili and English and the Kiswahili comprehension measure. On the other five measures of pronunciation and comprehension, there were no statistically significant, pre-treatment differences in academic performance between the treatment and comparison group members. In addition, children in classrooms with eReaders reported having more access to books at school and at home, but they were also older and significantly more likely to report that they “only read when they had to.”

Within treatment schools, LCA distributed 150 eReaders to Class 6 classrooms in February 2016 in proportion to the number of teachers and students at each school, with the intent for each school to have a sufficient number of eReaders to realize a one-to-one ratio between students and the tablets. All eReaders were loaded with Class 6 workbooks and supplementary reading in Kiswahili and English. Teachers integrated the tablets in math, reading, social studies, science, Kiswahili, and religion classes. Kiswahili, one of the official languages of Kenya, was the primary focus of instruction in 22 percent of observations.

Data collection and measures

Analyses of assessment and survey data were supplemented with emergent findings from a grounded theory analysis of data collected from classroom observations, student focus groups, and teacher interviews. Below, we describe our data collection processes and the resulting data sources in greater detail.

Assessment data

The program administrative data included baseline (pre-) test scores for assessing student achievement and end line (post-) test scores that enable us to examine associations between student tablet use and changes in their academic performance relative to other primary schools.
Because pilot testing suggested that the fluency and comprehension levels of Class 6 students would be too advanced for the Early Grade Reading Assessment (EGRA) and Progress in International Reading Literacy Study (PIRLS) assessments, a custom evaluation tool was developed by a LCA Monitoring and Evaluation (M&E) team member, drawing on the EGRA and PIRLS assessments, as well as input from a U.S.-based elementary school psychologist who regularly uses standardized assessments to evaluate reading abilities of primary school children. The assessment consists of a reading abilities evaluation containing three subtests on pronunciation, oral reading fluency, and comprehension in both Kiswahili and English, sourced from Class 8 Kiswahili and English textbooks. The scoring of student performance on the assessments was calculated individually per subtest. Pronunciation of each word was scored on a 0-1 scale, where 1 point was awarded for the correct pronunciation or 0 points otherwise. During the reading passages, the students’ total reading time and number of incorrectly read words were tracked. Both metrics were used to calculate correct words per minute (CWPM). The comprehension section included multiple-choice questions, one-answer open-ended questions, and multiple-answer open-ended questions.

Student surveys

A student survey was also administered to gather baseline information on student demographics, home environments, study habits, etc. (see again the measures in Table 1), as well as during the endline assessment, which included an additional set of questions to gauge students’ educational aspirations. A total of 109 students from treatment schools and 144 students from comparison schools completed the baseline academic assessments and survey in January and February of 2016. These same assessments were completed by 112 students from treatment schools and 136 students from comparison schools at the end of the school year (in
November 2016). After linking the baseline and endline data to the survey data, a total of 223 observations with complete records were available for analysis—95 students in the treatment group and 128 students in the comparison group (as shown in Table 1).

Classroom observations

We also conducted classroom observations of tablet use in the summer of 2016 in North Kamagambo, Kenya. Across all classroom observations, we used a well-tested, research-based instrument that enables observers to record the extent to which an instructional session (and integration of educational technology) facilitates quality learning opportunities for students (Burch, Good, & Heinrich, 2016), with some minimal adaptations to account for differences in classroom language use and infrastructure in rural Kenya. The observation instrument incorporates multiple dimensions that capture aspects of the physical environment; curricular content and structure; instructional model; interactions between teachers, students, and the technology; student and teacher engagement, and any assessment of learning. The ratings of digital and blended instruction are recorded on a 0-4 (5-point) scale; see additional information on each dimension in Appendix S.1 (online). Researchers also recorded time lost to technology problems, the number of students per device, time allocated to various instructional strategies, and detailed narrative vignettes of instruction, activities, and interactions in the classroom. A total of 36 classroom observations were conducted in the treatment and comparison schools.

Student focus groups

During endline data collection, a random sample of students from both treatment and comparison schools participated in focus group discussions. Students were asked to provide their opinions on the use of eReaders in treatment schools and more generally on reading behaviors in treatment and comparison schools. (The full focus group protocol is available in Appendix S.2
online). A total of 17 students from treatment schools and 26 students from comparison schools participated in the focus groups.

Teacher interviews

The research team also conducted interviews with teachers to provide context and insight into teachers’ experiences. The interview data were collected using a semi-structured interview protocol with interview topics, probes, and both closed- and open-ended questions. The interview topics included instructor background, instructional practices, support for tablet use, tablet access and use by student subgroups, assessment of the effectiveness of tablets in the classroom, and plans for their ongoing use. (Refer to online Appendix S.3 for the full protocol). In total, eight classroom teachers were interviewed.

Methods of analysis

We analyzed data both quantitatively and qualitatively, using triangulation across sources of information, classrooms, and settings to confirm the validity and reliability of analytical findings. In analyzing the qualitative data, interviews and focus groups were recorded, transcribed, and subsequently analyzed in conjunction with observation and survey data on tablet use in the classroom to identify emerging themes using a grounded theory approach. Spot-checking was used to check coding consistency. We also searched for exceptions and alternative explanations to challenge preconceptions and personal biases.

In quantitative analyses of the relationship of tablet use to student academic outcomes, we estimated two alternative specifications of the model predicting student achievement: one that predicts the change in student achievement [1] from the beginning to the end of the 2016 school year (with the gain score as the dependent variable, $A_{it} - A_{it-1}$), and the other [2] that predicts the
endline level of student achievement ($A_{it}$), controlling for the baseline student achievement (on the same measure) and other student characteristics at baseline ($X_{it-1}$), as shown in Table 1.

\[ A_{it} - A_{it-1} = \alpha + \beta_1 e_{R_{it}} + \beta_2 X_{it-1} + \varepsilon_{it} \quad [1] \]

\[ A_{it} = \alpha + \beta_1 e_{R_{it}} + \beta_2 X_{it-1} + \beta_3 A_{it-1} + \varepsilon_{it} \quad [2] \]

We also estimate robust, clustered standard errors that account for student clustering within classrooms. In this estimation, we do not make any causal assertions about the relationship between eReader use ($e_{R_{it}}$) and changes in student achievement, as we observe baseline differences between students in eReader and comparison classrooms that suggest the potential for unobservable differences in student characteristics as well.

**Findings**

Our mixed methods analyses identified improvements in the educational opportunities experienced by students in classrooms where the eReaders were integrated, including increased access to educational materials, enhanced student engagement, and gains in academic achievement. Our analysis also highlighted multiple barriers to effective eReader integration, such as inconsistent access to electricity, device sharing, and difficulties leveraging eReaders to transform instructional practices, that could inform changes to further improve the impact of eReaders in similar low-resource educational settings.

**Improvements in educational opportunity**

While the number of tablets afforded by Worldreader grant was insufficient to maintain the intended one-to-one student-to-device ratio in all classrooms, seven of the eight interviewed teachers at tablet schools emphasized that the devices increased student access to textbooks. Prior to tablet adoption, as many as eight students shared a textbook. In other instances, only the teacher had access to course material, which he or she used to copy all exercises onto the
whiteboard for students to copy into their exercise books. One teacher stated, “In a class environment with no books, the tablets help each pupil to work at their own pace because they each have their own tablet—they can use them anytime. They don’t have to share with anybody.” Students in Kenya who participated in end-of-the-school year focus groups also gave positive feedback on the implementation of tablets in their classrooms and unanimously expressed a preference for tablets over standard textbooks. They highlighted aspects of the tablets such as their ability to efficiently find definitions of unknown words and to access interesting and varied books, and the fact that the tablets didn’t have missing pages like their textbooks.

We accordingly observed high levels of digital citizenship, or the extent to which students used the eReaders as intended by the instructor. Comments from teachers suggested that the observed behavior reflected students’ respect and appreciation for the opportunity to use tablets and classroom cultural norms regarding teacher authority. Teachers also noted in interviews that the tablets had improved student engagement. Teachers’ evidence for this included decreased student absenteeism and drop-out rates, as well as an observed shift in students’ attitudes toward learning. With respect to students’ physical attendance, one teacher stated that since they received tablets, students were rarely absent. Another provided specific numbers, saying that, “In the past, we had two to three (drop-outs) per term, but this time, they have not (dropped out).” Yet another teacher mentioned that at least three students transferred to the tablet schools from other schools.

Teachers attributed these changes to a shift in students’ mindset associated with the opportunity to use tablets. As one teacher explained, “Now pupils like school. Being in school leads to getting something out of that school.” Teachers described students as working more
without being told, even without the teacher present in the room, as well as students coming in as early as 6:30 in the morning to read storybooks on the tablets. Furthermore, they suggested that tablets increased motivation among students in other classes, who attempted to compete with the students with tablet access. One teacher also mentioned that the tablets improved teacher-student relationships by increasing opportunities to communicate with one another. This was evident in classrooms where more individual students could be called on to read or engage in questions in class, since they had access to the text via the tablets.

Given the increased access to educational resources and improved student engagement identified in classroom observations and noted by teachers, it is not surprising that our analysis of student performance from baseline to endline assessments shows that students in classrooms with eReaders consistently experienced larger academic achievement gains on the oral reading fluency and reading comprehension measures (in Kiswahili and English) compared to students in the comparison classrooms (without eReaders), although only about one-third of these differences are statistically significant. Table 2 summarizes the results of these estimations for each of the academic performance measures (for both specifications above), and it also shows the estimated changes in student performance controlling only for their baseline academic performance and adjusting for student clustering in classrooms.

The improvements in oral reading fluency and comprehension are larger (and more often statistically significant) for English reading skills. Controlling for student characteristics also increases the magnitude of the estimated differences. These findings are supported by student comments in focus groups who self-reported improved grades that they attributed to the tablets, while others cited higher rankings on national exams. Teachers also reported higher academic
Table 2: Estimated changes in student academic performance associated with eReader use

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Predicting gain scores</th>
<th>Predicting endline academic performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test control only</td>
<td>All controls</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Δ in Kiswahili correct words per minute</td>
<td>222</td>
<td>16.539</td>
</tr>
<tr>
<td>Δ in English correct words per minute</td>
<td>198</td>
<td>23.206</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension</td>
<td>222</td>
<td>0.918</td>
</tr>
<tr>
<td>Δ in English comprehension</td>
<td>222</td>
<td>0.883</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension (incorrect)</td>
<td>222</td>
<td>-0.807</td>
</tr>
<tr>
<td>Δ in English comprehension (incorrect)</td>
<td>222</td>
<td>-0.725</td>
</tr>
<tr>
<td>Kiswahili correct words per minute</td>
<td>222</td>
<td>1.923</td>
</tr>
<tr>
<td>English correct words per minute</td>
<td>198</td>
<td>7.640</td>
</tr>
<tr>
<td>Kiswahili comprehension</td>
<td>222</td>
<td>0.260</td>
</tr>
<tr>
<td>English comprehension</td>
<td>222</td>
<td>0.763</td>
</tr>
<tr>
<td>Kiswahili comprehension (incorrect)</td>
<td>222</td>
<td>-0.423</td>
</tr>
<tr>
<td>English comprehension (incorrect)</td>
<td>222</td>
<td>-0.834</td>
</tr>
</tbody>
</table>

Note: Estimated effects (coefficients) in boldface are statistically significant at α=0.05.
achievement among students after receiving eReaders, citing improved and faster reading ability among students as well as higher achievement in writing, math, and science.

Challenges to successful technology integration

Despite promising shifts in students’ educational experiences in classrooms with eReaders, several barriers to effective integration remained that limited the extent to which the full potential of eReader use was realized. One of the most pressing concerns raised by teachers was limited access to electricity and related challenges keeping tablets charged. Some, but not all schools, reported access to a generator. Teachers from other schools traveled long distances to charge the tablets at one of the other schools or charged the tablets at their personal residences. Greater investment in electricity infrastructure and the equitable distribution of tablets across all schools could have reduced between-school disparities in tablet access.

In addition to charging issues constraining the number of tablets available on a given day, we only observed a one-to-one student to tablet ratio in 32 percent of the classroom sessions, limiting the ability of students to take full advantage of features that facilitated personalized learning, such as adjusting the font size to improve readability, working at one’s own pace, and taking the tablet home. At the same time, we observed that device sharing could facilitate peer-to-peer learning and collaboration, indicating a one-to-one ratio was not a necessary condition for learning with the tablets. In fact, Haßler, Major, and Hennessy (2016) suggest that with the high relative advantage tablets provide in many low-resource settings, targeting a one-to-one student to device ratio may not be the best use of limited resources. Instead, the same funds may be better used to enhance professional development for teachers on device use and integration (Haßler et al., 2016). Indeed, it would have been advantageous to
offer more professional training to the rural Kenya teachers on how to leverage tablets for multiple learners working on a single device.

Beyond infrastructure barriers, the introduction of eReaders was not combined with concerted efforts to assist teachers in transforming instructional practices to be more student-centered. Regardless of eReader access, most lessons consisted of teachers copying notes onto the board, teachers lecturing about the notes, and students copying the notes or practice questions into their exercise books. We rarely observed teachers engaging with students (or interacting with the tablets) in a manner that invited student dialogue. Reflecting cultural norms, teachers seldom asked students to demonstrate their understanding of the skills being taught until the very end of the lesson (on their homework, checked by teachers after class).

Further, due to overall high student-teacher ratios, most teachers relied on student technology expertise to resolve any technical issues, resulting in differential access to reading material. In the absence of options to provide accommodations on the eReaders, teachers often excluded students experiencing academic challenges (or “slow learners” as teachers described them). Teachers reported that “slow-learners” experienced more difficulties using the eReaders; one teacher specifically stated, “We don’t have enough time in a lesson to help every pupil access (the eReader), so slow learners cannot use eReaders during lessons. If you go one by one to teach them how to open a page, the lesson will be over.”

While some teachers made the effort to support every student in using the eReaders, this was not the case in all classrooms. Some teachers paired students struggling with the eReaders with students perceived as higher performing. This type of pairing provided learning opportunities for both the student providing and the student receiving support. In addition, a few teachers mentioned that tutorials or reading clubs were designed to support students who
struggled both in reading and with the eReader manipulation, although observations at the schools revealed that only one school held reading club meetings regularly. Greater support and ongoing professional development for teachers in these and similar programs might have facilitated greater tablet access for students with lower reading levels and technical competencies.

**Research and policy implications**

Findings demonstrating improved rates of student learning and enhanced educational experiences represent preliminary but promising evidence of the potential for eReaders to increase student literacy and academic performance in contexts such as rural Kenya. At the same time, challenges in implementation across settings that are exacerbated in low-resource contexts suggest that the success of technology integration in transforming student learning is contingent on responsiveness to local capacity needs (e.g., infrastructure) and cultural factors that shape teacher-student interactions around eReaders (Cuban, Kirkpatrick, & Peck, 2001; Rogers, 2003). Our research also highlighted several policy levers and school-based strategies likely to improve equitable access to quality learning experiences considering persistent infrastructure challenges within this and other similar contexts.

Developing and implementing a successful educational technology initiative requires an ongoing administrative commitment to supporting and leveraging resources, including a base level of infrastructure (e.g., a consistent power source) and access to technical expertise, which in low resource contexts may require external support such as that provided by the LCA in this study. School leadership often also plays a role in supporting the development and success of supplemental programs, such as tutorials and reading clubs that may increase and enhance the use of eReaders. Where reliable Internet access is not available, access to pre-loaded educational
resources may be a feasible alternative for expanding learning opportunities (Wang, 2016). Additionally, the availability of additional devices to support a one-to-one student to device ratio could promote greater intensity of use, as well as opportunities for more personalized and out-of-school learning. However, in settings such as rural Kenya where the relative advantage of devices is high, even when shared, the benefits of reducing the student to device ratio must be weighed against potential advantages of other investments, such as expanding professional development on device integration (Haßler et al., 2016).

Observations of ICT integration in classrooms highlighted opportunities for peer-to-peer learning and exchange (both among teachers and students) to improve technical expertise and reduce technical issues. Building shared capacities among teachers may also increase the timeliness of support for ICT integration, which is critical to ensuring both quantity and quality of instructional time, with implications, in turn, for classroom management, student engagement, and teacher availability to support learning as well as student academic outcomes. Therefore, in-school (and classroom) expertise is critical, with teacher peer assistance, mentoring, and learning a potentially valuable strategy (in combination with ongoing professional development) for transmitting content-specific integration strategies and improving pedagogical practice with device use (Boschman, McKenney, Pieters, & Voogt, 2016). Recognizing and drawing on students’ technical skills in a similar manner can also have the added benefit of encouraging teamwork and fostering student enthusiasm for technology use (Ciampa, 2014). The advantages of peer learning should be balanced, however, with potential equity concerns, so that the teaching and learning of more technically proficient students is supported as well and not deprioritized in the process.
Across classrooms, equity in access to educational technology and its effective use was a persistent concern, but our research suggests that schools and teachers have levers at hand for better engaging and supporting those in need. Indeed, an important benefit of increased access to educational technology in low-resource settings is the opportunity it affords teachers to allocate more time to working directly with students (Ferrer, Belvis, & Pàmies, 2011). Our work also shows that concerted effort is needed to ensure that this most valuable educational resource, the instructor’s attention, is equitably distributed in ways that discourages the emergence of within-classroom tracks with differential access to quality learning experiences, such as some teachers’ disregard of “slow learners” in the classroom. In our study, some observed strategies for addressing technical challenges, such as tablet sharing and assigning peers to mentor other students on technology use, could also increase or decrease students’ ability to benefit from technology access, depending on implementation.

Our findings on associations between tablet use, student engagement, and test scores, along with prior research demonstrating associated achievement gains, strengthens the emerging evidence base that suggests with sufficient support and resource allocations, educational technology can be instrumental in enhancing learning opportunities, and in turn, lessen education and digital divides for students in low-resource settings across the globe. However, continued emphasis must be placed on designing, implementing, and supporting initiatives in a manner that minimizes barriers to effective use and ensures equitable access across and within classroom settings.
References


