The Potential and Prerequisites of Effective Tablet Integration in Rural Kenya

Carolyn J. Heinrich*
Patricia and Rodes Hart Professor of Public Policy and Education
Department of Leadership, Policy, and Organizations, Peabody College
Professor of Economics, College of Arts and Sciences
Vanderbilt University
230 Appleton Place, Nashville, TN, USA; +001 615 3221169
Email: carolyn.j.heinrich@vanderbilt.edu
Phone: +001 615-322-1169, Fax: +001 615-343-7094

Jennifer Darling-Aduana
PhD student in Leadership, Policy, and Organizations, Peabody College
Vanderbilt University.
Email: jennifer.s.darling@vanderbilt.edu

Caroline Martin
Research Analyst
Tennessee Department of Education
Email: Caroline.Martin@tn.gov

June 2019

Acknowledgments: We thank Mr. Jaime Davila and Vanderbilt University for financial support of this research. We also thank the school principals and teachers in Dallas Independent School District and in North Kamagambo, Kenya who opened their classrooms to observation by the research team and participated in interviews. We also greatly appreciate the Jiv Daya Foundation and the Lwala Community Alliance (LCA) for their partnership in this research effort, including support provided by staff in data collection and other contributions to the research: Esmeralda Garcia-Galvan, Christi Kirshbaum and Christopher J. Ryan, and LCA staff Staci Sutermaster, Joseph Starnes and Liz Chamberlain.
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 and infrastructure improvement efforts have 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 pedagogical, 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 pedagogical, cultural and institutional factors interact with technical knowledge in ICT integration in ways that support or constrain student learning.

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 general technical knowledge 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 cultural factors that interact with pedagogical and technical skills to ensure that classroom instructors’ attention is equitability distributed in ways that discourage 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 how pedagogical, cultural and institutional factors interact with technical knowledge in education technology integration and how they relate to equitable and effective 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 learning, as well as their implications for reducing educational and digital divides. We employ a mixed methods, quasi-experimental (pre-post, non-equivalent control group) research design that draws on data from classroom observations, teacher interviews, student surveys and focus groups, and assessments of student academic performance to generate evidence on classroom practices and student learning in schools with access to tablets, while also highlighting core 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 where schools may lack sufficient funds to meet basic operating and educational costs that support access to physical infrastructure, technical capacity, and human capital (Herodotou, 2018; Twining, Raffagelli, 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, which build on rural electrification efforts initiated with the 2006 Energy Act.

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 a setting in rural Kenya, where public schools and a community-based, non-profit partner 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, was tablet integration associated with any observed changes in 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**

*Theoretical framing*

Two of the most widely used frameworks for conceptualizing investigations of ICT integration are the SAMR (Substitution, Augmentation, Modification, and Redefinition) and TPACK (Technological Pedagogical Content Knowledge) models (Puentedura, 2013; Mishra & Koehler, 2006). The SAMR (see Figure 1) provides a scaffold for characterizing learning tasks in terms of the depth and complexity of technology integration, broadly classifying technology use as either enhancement or transformation. We situate the use of technology in North Kamagambo
Figure 1: SAMR (Substitution, Augmentation, Modification, and Redefinition) Model

Redefinition
Tech allows for the creation of new tasks, previously inconceivable

Modification
Tech allows for significant task redesign

Augmentation
Tech acts as a direct tool substitute, with functional improvement

Substitution
Tech acts as a direct tool substitute, with no functional change

Puenteedura, 2013
schools primarily in the enhancement domain, in part because of limitations of the technology (eReaders) and the ICT infrastructure (e.g., lack of Internet access). In the most basic form (substitution), teachers use technology as a substitute for previous instructional approaches, with no changes in instructional processes. To the extent that technology use improves on teaching or learning processes (that could be undertaken with or without technology), the SAMR categorizes this technology use as augmentation (Puenteledura, 2013). Alternatively, for technology use to facilitate transformative teaching—that substantially alters learning tasks in ways not possible without the technology—teachers are expected to use technology for the significant redesign or reimagining of instructional approaches and learning opportunities (Puenteledura, 2013).

Factoring into teacher approaches to technology integration in the classroom are not only their knowledge of the technology and how to enact features embedded in it for enhancing or transforming learning (Orlikowski, 2000), but also their pedagogical and content knowledge, as shown in the TPACK model in Figure 2 (Mishra & Koehler, 2006). This framework identifies intersections of two or three of these domains (technological, pedagogical and content knowledge) that illuminate our understanding of how teachers conceive of and enact technology in ways that are consistent with their pedagogical beliefs and practices and/or their content expertise (Hilton, 2015). In our study of eReader (tablet) integration in North Kamagambo, Kenya, we focus primarily on the TPK (technological and pedagogical knowledge) intersection in the TPACK model, given that the eReaders are used to support access to books (in a variety of subjects) for language learning and reading comprehension. We also draw sociocultural theory into our discussion of these domains, which brings in the view that cultural norms and conventions transacted by students and teachers in the classroom will likewise influence how teachers and students understand the properties of the tablets and whether and how they rely on
Figure 2: TPACK (Technological Pedagogical Content Knowledge)

Mishra & Koehler, 2006
other individuals and resources in the classroom to support their learning with them (Nasir & Hand, 2006). For example, the TPK intersection motivates us to examine how teachers deploy their technological and pedagogical knowledge in grappling with the limitation of an insufficient number of tablets to facilitate one-to-one device access in their classrooms, while sociocultural theory leads 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. Used in combination, these theoretical frameworks help us to identify, classify, and interpret the pedagogical, cultural, institutional, and technical factors observed in this study of ICT integration.

_Evidence on ICT integration in low-resource settings_

Existing research confirms that a range of pedagogical, cultural, institutional, and technical 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). This personnel challenge also likely reduces the pool of technical knowledge available to educators in a given school, particularly in countries where professional development on ICT integration is limited. And it may further dilute the effectiveness of technology-based initiatives in subsequent years and preclude teachers from moving beyond substitution (in the SAMR) to reimagining what is possible with technology use. Research shows that even when teachers have confidence in or experience with the technology being introduced, they are frequently challenged in low-resource contexts 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-Aduana & 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 technology use 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 expand general technical knowledge that is foundational to enhancement and transformation (in SAMR) and to the interaction of technological and pedagogical knowledge (TPK) in ways that support 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 pedagogical, 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 began 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. With the objective of understanding how the introduction of the eReaders would affect student learning, the LCA implemented a quasi-experimental, non-equivalent control group design when selecting schools to participate. The LCA Education Team first categorized all 13 schools 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, while also factoring in both the treatment and control schools’ commitment to working with LCA and the intent to involve one school from each sub-area.

Because the selection of classrooms for eReader distribution was made via the criteria discussed above (and not via random assignment), we adjust for pre-treatment differences in estimating *associations* between the eReader program and student outcomes and do *not* interpret
any estimates as causal. 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 additional baseline survey questions designed by the LCA were intended to gauge students’ access to books at school in the absence of eReaders, as well as at home, and to measure student motivation to read and caregiver support of reading and learning at home. These descriptive statistics show that students in classrooms receiving the eReaders scored significantly lower on three measures of academic performance at baseline (before the 2016 school year): oral reading fluency in Kiswahili and English, and Kiswahili comprehension. 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 at baseline, 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.
| Table 1: Baseline Characteristics of eReader Treatment and Comparison Groups, 2016 School Year |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                 | Treatment group |                | Comparison group |                | Mean difference (T-C) | p-value |
|                                 | N (students)    | Mean           | Std. Dev.        | N (students)    | Mean           | Std. Dev.        | 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.

†Some students did not complete the English correct words per minute assessment, resulting in fewer observations for analysis of this outcome. Analyses were conducted to assess the sensitivity of study findings to this loss 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 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—although as indicated in Table 1, some students did not complete the English CWPM assessment. Our analysis of the sensitivity of our results to the loss of observations (without English CWPM) did change any research conclusions.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 regression analyses of the relationship of tablet use to student academic outcomes, we estimated two alternative specifications: one that estimates 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 described in Table 1.

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

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

We estimate robust, clustered standard errors that account for student clustering within classrooms. Given the 2016 rollout of the eReader program, we only have one baseline measure of achievement, and because we observe baseline differences between students in eReader and comparison classrooms (suggesting potential for unobserved differences in student characteristics as well), we do not make any causal assertions about the relationship between eReader use \((eR_{it})\) and changes in student outcomes. Nonetheless, research has established that
the use of value-added models such as these that control for lagged measures of the dependent variables often substantially reduce bias in estimates (Chetty, Friedman, & Rockoff, 2014).

**Findings**

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

**Improvements in educational opportunity and outcomes**

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.” This represents an augmentation of learning tasks in the SAMR framework (Puentedura, 2013). 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. The students’ perspective likewise illuminates how the tablets augmented learning opportunities, providing functional improvements over the textbooks they replaced.

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, a change potentially
leveraged by advances in technological and pedagogical knowledge (TPK) through tablet integration. This was evident in classrooms where teachers could call on more individual students to read or engage in questions in class, since they had access to the text via the tablets. These teachers described tablet use as not only changing the context of learning in their schools by redefining students’ orientation to school—potentially because of the status associated with learning via technology in these settings—but also as augmenting prior classroom practices by facilitating communication and improving access to course materials. Here we share excerpts from two classroom observation vignettes that illustrate these enhanced interactions:

*The teacher called on more than 20 students to read from the eReader. He paused them if they were having trouble pronouncing a word or reading punctuation correctly and would either correct the student or ask the class to correct the student. The teacher would then have that student continue (sending message that it was okay to struggle). The teacher paused to adjust the font size for a student having difficulty. When asking comprehension questions, the teacher holds students accountable to providing text-evidence by asking students to provide the page number and paragraph for where they found their answer [in the eReader]. 42 e-readers were charged, so most students had one they could refer to, giving them the opportunity to use it for their individual needs (font size, looking up vocabulary words they didn't understand, etc.).”*

*The teacher has very good rapport with students. There are many opportunities for participation and quality learning/critical thinking. The teacher takes extra time at beginning of class to make sure students are on the correct page and that everyone has access to an eReader at their bench (even if they must share with 4 other students). The teacher uses every opportunity he can to have students engaging with the eReader by asking them to read the vocabulary words, read the practice sentences, come up with their own sentences, and work independently, so that students are talking almost the same amount of time as the teacher.*

The increased access to educational resources and improved student engagement identified in classroom observations and noted by teachers were consistent with greater improvements in oral reading fluency and reading comprehension (in Kiswahili and English) observed among eReader users compared to students in classrooms without eReaders. Our (value-added) regression analysis of student performance from baseline to endline assessments
shows that students in classrooms with eReaders consistently realized larger increases in academic performance, although only about one-third of the differences were statistically significant. Table 2 summarizes the regression results, presenting the coefficient estimates for the treatment (eReader) indicator for each of the academic performance measures for the two model specifications (equations 1 and 2 above)—separately with pre-treatment controls only (for baseline academic performance) and including all controls shown in Table 1—while also adjusting for student clustering in classrooms.

The estimated 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 consistent with 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 better academic performance among students after receiving eReaders, citing improved and faster reading ability 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 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. While the Kenyan government continues to support rural electrification efforts, further investments in basic
infrastructure and the equitable distribution of tablets across all schools will be needed to reduce between-school disparities in tablet access.

<table>
<thead>
<tr>
<th>Table 2: Estimated changes in student academic performance associated with eReader use (value-added regression analysis results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in academic performance from baseline to endline (1)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Δ in Kiswahili correct words per minute</td>
</tr>
<tr>
<td>Δ in English correct words per minute</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension</td>
</tr>
<tr>
<td>Δ in English comprehension</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension (incorrect)</td>
</tr>
<tr>
<td>Δ in English comprehension (incorrect)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predicting endline academic performance (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Δ in Kiswahili correct words per minute</td>
</tr>
<tr>
<td>Δ in English correct words per minute</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension</td>
</tr>
<tr>
<td>Δ in English comprehension</td>
</tr>
<tr>
<td>Δ in Kiswahili comprehension (incorrect)</td>
</tr>
<tr>
<td>Δ in English comprehension (incorrect)</td>
</tr>
</tbody>
</table>

Note: Estimated effects (coefficients) in boldface are statistically significant at α=0.05.
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. The increased use of peer-to-peer learning and collaboration marked one of the most notable deviations from teacher-directed, lecture-based instruction observed in most classrooms. The resulting opportunities for student agency represent a partial redesign of instructional processes in a manner that began to transform relational dynamics and academic expectations in the classroom.

Beyond the opportunities for peer collaboration facilitated through device sharing, 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 still 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. It was relatively rare to observe 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). The general lack of (SAMR) transformative
practice using the tablets highlights the importance of pedagogical as well as technological
knowledge, per the TPK intersection (Mishra & Koehler, 2006). This reflects not only a human
(instructional) capacity limitation but also the challenge of transforming and reimaging
pedagogical practices in any institutional setting—regardless of the tools available—when doing
so runs counter to cultural norms and practices. This excerpt from a classroom observation
vignette is illustrative of typical pedagogical practice:

The teacher reviewed the previous lesson and then clearly stated the heading students
should be on for the new subtopic and walked around to make sure students were there.
Most of the rest of the lesson consisted of the teacher walking through the topic and
lecturing with his paraphrases from eReader notes, and then asking students to tell him
answers to questions he asks using the eReaders. Some students who struggle with
English have a hard time following because they are not given time to read.

The above excerpt also points to the lack of accommodation for students at different
levels of learning. Further, due to overall high student-teacher ratios, many teachers relied on
student technology expertise to resolve 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.” The respect accorded to teachers as
givers of knowledge and the belief that students were responsible for their own learning in the
instructional settings limited the tablet access of students classified as “slow learners.” In this
way, tablet use may have exacerbated, or at the very least replicated, existing stratification based on ability.

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 enhanced learning opportunities and more engaging 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), support for transforming pedagogical practice with technology, and cultural factors that shape teacher-student interactions around eReaders (Cuban, Kirkpatrick, & Peck, 2001; Rogers, 2003). Specifically, the importance of cultural norms and practices should not be underestimated when anticipating the extent to which tablet use may be leveraged to transform, rather than merely enhance, current instructional
practices. 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), access to general technical knowledge, and professional development for pedagogical practice, 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). In fact, device sharing can serve as an impetus to begin transforming instructional practices in a manner that embeds students with greater agency through peer-to-peer learning and collaboration, in contrast to teacher-directed, lecture-based instruction.

Observations of ICT integration in classrooms also highlighted opportunities for this type of peer-to-peer learning and exchange (both among teachers and students) to improve technical knowledge and pedagogical practice with device use and reduce technical issues. Building
shared capacities among teachers may also increase the timeliness of support for ICT integration, which, in combination with ongoing professional development, 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 (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 equitability 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 student engagement and performance in classrooms where tablets were integrated strengthens the emerging evidence base that suggests with sufficient support and resource allocations, educational technology has the potential to 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


**Endnote**

1 We created an indicator variable for students missing the English CWPM measure and first descriptively examined whether students who were missing this information differed from students who did complete this assessment. We then imputed values for those missing the English CWPM measure and included the dummy variable indicating it was originally missing in the regression analysis of student outcomes. The results (coefficient estimates on the eReader treatment variable and other control variables) differed negligibly, and the dummy variable for missing data was not statistically significant.