Mobile Learning During School Disruptions in Sub-Saharan Africa

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Abstract

School closures due to teacher strikes or political unrest in low-resource contexts can adversely affect children's educational outcomes and career opportunities. Phone-based educational technologies could help bridge these gaps in formal schooling, but it is unclear whether or how children and their families will use such systems during periods of disruption. We investigate two mobile learning technologies deployed in Sub-Saharan Africa: a text message-based application with lessons and quizzes adhering to the national curriculum in Kenya (N=1.6m), and a voice-based platform for supporting early literacy in Côte d'Ivoire (N=750). We examine usage and beliefs surrounding unexpected school closures in each context via system log data and interviews with families about their motivations and methods for learning during the disruption. We find that mobile learning is used as a supplement for formal and informal schooling during disruptions with equivalent or higher intensity, as parents feel responsible to ensure continuity in schooling.

Keywords

Education technology, school disruption, mobile learning, mixed methods, Kenya, Côte d'Ivoire

Introduction

Around the world, school children and their families rely on governments to provide access to education. The official academic calendar organizes the year into periods of schooling and school breaks to recognize major holidays, provide students with time to prepare for exams, and account for agricultural needs that are still relevant today in some societies. However, there are also unplanned disruptions to schooling that can arise for a variety of extenuating circumstances, such as internal labor disputes resulting in teacher strikes (Wills et al. 2014), natural disasters like hurricanes (Force 2013), and public health crises like the COVID-19 pandemic which has disrupted in-person instruction around the world (Lee 2020). The frequency of these unplanned disruptions and availability of resources to overcome them systematically varies across different parts of the world. Sub-Saharan Africa is not only home to the lowest level of educational access in the world (UNESCO Institute for Statistics 2016), it has also undergone many unplanned disruptions in schooling in recent history, especially due to civil unrest which can last for several weeks (Gleditsch et al. 2002; Leithead 2017; Verwimp and Van Bavel 2014; Abadzi 2009). These frequent disruptions to schooling are detrimental for student learning outcomes and for building a highly skilled workforce to spur economic development in the region.

Recognizing the vital role of schooling, students and their families in Sub-Saharan Africa have started using educational technologies to supplement formal schooling during times of disruption. Although physical resources like classroom space are scarce, it is projected that mobile connectivity will reach over half of Sub-Saharan Africa by 2025 (GSM Association 2018). As prices drop, basic phones and increasingly smartphones are expanding access to learning opportunities in a region where traditional desktop computers or laptops are economically not as feasible as in the developed world (Wagner 2014). In this research, we consider the use of mobile learning during school disruptions in two countries in Sub-Saharan Africa: Kenya and Côte d'Ivoire.

Current rates of educational access in Sub-Saharan Africa are among the lowest in the world due to a shortage of physical resources (UNESCO Institute for Statistics 2018). In 2010, Kenya had the 9th highest rate of children without education in the entire world (Clark 2015). Even among students in school, only 30% of third-grade students achieved second-grade competencies, with a substantial discrepancies in achievement between students of higher and lower socioeconomic status (Uwezo 2016). In Côte d'Ivoire, students are less likely to complete primary school and have lower literacy levels than many other Sub-Saharan West African countries. In 2014, 94% of Ivorian primary school-aged students were enrolled in school, but only 61% completed primary school and only 50% of primary school-aged students reached the expected literacy level (PASEC 2014). The causes of these gaps in educational attainment and literacy are complex and include family participation in agricultural labor, and they are compounded by disruptions in instructional time due to school closures.

Technology has been adopted to support education in low-resource contexts and developing countries by providing resources to students and their families (West and Ei 2014;

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Pouezevara and King 2014; Valderrama Bahamondez et al. 2011; Valderrama Bahamóndez et al. 2014; Poon et al. 2019), as well as teachers (Varanasi et al. 2019, 2020; Cannanure et al. 2020; Konagai 2020). Increasingly, they leverage ubiquitous mobile devices to supplement schools' instruction (Porter et al. 2016). In some cases, mobile devices are used exclusively in schools (Warschauer and Ames 2010). In other cases, they are designed for learning outside of school to provide students the opportunity to continue learning at home and in their community (Kumar et al. 2012; Valderrama Bahamóndez et al. 2014), even if they miss school for farm work, or, potentially, if the schools are closed. How well these approaches work in areas with limited access to technology or internet access warrants further investigation.

This study seeks to understand how mobile educational technology has been used to supplement education in Sub-Saharan Africa in the face of disruptions to in-person learning. We investigate this through two case studies. The first case is situated in Kenya in 2017 when schooling was disrupted by civil unrest due to a series of contested elections. Here we examine the extent to which students used a popular SMS-based study tool called Shupavu291 to keep learning outside of school. To this end, we analyzed 28 million logged records from over 1.6 million students who used the study tool between 2016-2018. The second case is situated in Côte d'Ivoire where members of our research team helped deploy a new voice-based application designed to improve childhood literacy, called Allô Alphabet. During the period of deployment with 750 students in 16 schools, an unexpected teacher strike disrupted schooling, while students retained access to the provided phones for accessing Allô Alphabet. We examined log data from the application and conducted interviews with families to understand their beliefs and practices around educational technology during the disruption. Our two case studies address the following research questions:

RQ1: To what extent is educational technology acting as a supplement for educational access during periods of disruption in schooling?

RQ2: How does students's use of educational technology differ during periods of disruption and periods of normal schooling?

RQ3: What are families' beliefs and involvement around educational technology usage during periods of disruption in schooling?

Our findings across two case studies show that mobile learning is used as a supplement for schooling during disruptions, especially as parents feel responsible to ensure continuity in schooling during times of disruption. We also find that students and their families engage in mobile learning during regular school breaks, which serves as preparation for sudden disruptions. In a complex ecosystem of formal and informal schooling, we find that educational technology plays the role of an informal learning opportunity, which gets adopted with relative ease, though family members encounter difficulties providing hands-on support during periods of school disruption. By combining big data analytics with in-depth interviews, our research contributes novel insight into how families and students use educational technology in general and specifically during periods of disruption.

Related Work

Impact of school disruption on learning

Significant public and philanthropic funding has been invested in ensuring that formal schooling is widely available in developing countries, while international commitments such as the United Nation's Sustainable Development Goals have motivated global initiatives to expand access to formal schooling. According to the World Bank, global primary school enrollment has increased from 72% to 91% since 1970, although more than half (57%) of out-of-school primary-aged children are in Sub-Saharan Africa*. Access to consistent instruction in schools may be disrupted by systemic shocks such as violent civil conflict (e.g., in Burundi (Verwimp and Van Bavel 2014), Tajikstan (Shemyakina 2011), and Perú (Leon 2012)), school-level impacts such as teacher absenteeism or teacher strikes (see (Abadzi 2009) for a review), or regional factors such as natural disasters (Baytiyeh 2019; Rush et al. 2016) or public health crises, such as AIDS (Benavot and Gad 2004), Ebola (United Nations Development Programme (UNDP) 2015) or COVID-19 (Hallgarten 2020).

In our first case study, we discuss ed tech usage during school disruption due to political violence in Kenya. In Sub-Saharan Africa more broadly, nearly three-fourths of countries have experienced some form of civil conflict in the last 40 years (Gleditsch et al. 2002). Among other significant economic, agricultural, and health impacts, children in regions with civil conflict are less likely to complete primary school (Verwimp and Van Bavel 2014), with girls often being more severely impacted than boys (Shemyakina 2011). In some cases, these impacts are due to family migration or displacement (Chamarbagwala and Morán 2011), families requiring their children to leave school to help with unexpected labor shortages (Justino 2011; Shemyakina 2011), or schools voluntarily closing or reducing formal instructional time by starting late or closing early to avoid local violence (Abadzi 2009; Benavot and Gad 2004).

In our second case study, we discuss ed tech usage during school closures due to teacher strikes in Côte d'Ivoire. Teachers' industrial actions, of which strikes are a part (also including work-to-rules, go-slows, overtime bans, and other actions (Wills et al. 2014)), are a feature of public education around the world, with particular motivations and methods situated in the unique political context in which they occur (Jaume and Willén 2019; Wills et al. 2014; Wong et al. 2014; Abadzi 2009; Benavot and Gad 2004). These strikes, while critical for teachers to advocate for better pay and improved working conditions, often result in unplanned closures of schools comparable to the effects of natural disasters (Wong et al. 2014). Such closures due to strikes have been shown to adversely impact students' learning outcomes, such as in a study of strikes in South Africa (Wills et al. 2014). They also negatively impact parents' labor as they take on increased

*https://data.worldbank.org/data-catalog/ed-stats

childcare responsibilities during extended school closures: Jaume and Willén (2018) reports this in the context of teacher strikes in Argentina, and others have reported impacts on parents' labor (primarily women) during the COVID-19 pandemic (Alon et al. 2020; Del Boca et al. 2020). Over a longer period, in their cross-cohort evaluation of over 1,500 teacher strikes in Argentina over a 30-year period, Jaume and Willén (2019) found significant impacts on children's future labor outcomes due to school closures resulting from teacher strikes.

Educational technology in developing contexts

Educational technology is frequently deployed in efforts to bridge gaps in formal schooling in developing contexts. Two meta-analyses of educational interventions in Sub-Saharan Africa demonstrate how investments in instructional technology, specifically adaptive systems, have a larger impact on student learning outcomes compared with funding nutritional and health interventions, reducing class sizes, or providing financial incentives for attendance (Conn 2017; McEwan 2015). Educational technologies have been implemented in many low-resource communities, using mobile devices in class (Valderrama Bahamondez et al. 2011) or in after-school programs (Kam et al. 2009), or on mobile devices used in both in-school and out-of-school contexts (Poon et al. 2019; Valderrama Bahamóndez et al. 2014; Kumar et al. 2012).

Researchers have studied how apps on e-readers (Rhodes and Walsh 2016) or tablets are used in schools (Phiri et al. 2014) and in homes (Uchidiuno et al. 2018). However, with few exceptions (e.g., Poon et al. 2019; Kam et al. 2009), these systems have been designed for smart devices (Valderrama Bahamondez et al. 2011; Kumar et al. 2012; Ojanen et al. 2015; Jere-Folotiya et al. 2014; Uchidiuno et al. 2018), despite significantly fewer families in rural communities owning smartphones than low-cost feature phones (Lucini and Bahia 2017; Lucini 2016). Even in cases where families owned both smartphones and feature phones, as in Poon et al. (2019), they reported that parents preferred that their children use feature phones.

Educational technologies have been proposed as ways of supporting continuity of learning during crises. Baytiyeh (2019) proposed using digital tools to maintain access to learning materials and communication with instructors and peers following natural disasters, highlighting the importance of maintaining social relationships to teachers and peers and the role of parents in mitigating the mental stress of learning during a crisis. Others, such as Rush et al. (2016) highlight the critical role that infrastructure plays in emergency online learning in a crisis, including the importance of using low-cost, widely accessible technologies. Prior work has discussed the role of technology in maintaining continuity of learning during school closures due to epidemics (e.g., SARS, Fox 2004, and COVID-19, Huang et al. 2020; Hall et al. 2020; Teräs et al. 2020), although with few exceptions (Mhlanga and Moloi 2020; Angrist et al. 2020; Teräs et al. 2020) these studies focus on high-income countries with more widespread access to broadband internet and technology for online learning (Huang et al. 2020; Fox 2004; Hall et al. 2020; Andrew et al. 2020; Hammons 2017).

However, in many Sub-Saharan contexts, the majority of learners may not have access to the internet or devices that can access online learning content (Lucini 2016). Design choices around device usage for educational technologies are critical, as gaps in access to smart devices are likely to fall along socioeconomic lines (Lucini and Bahia 2017). Socioeconomic divisions may thus be exacerbated by wealthier children having access to technologies to supplement their learning (Bakermans-Kranenburg et al. 2005; Lamb 2011). Thus, no- or low-technology interventions may be more appropriate to support continuity of learning during periods of disruption. In Botswana, Angrist et al. (2020) deployed an intervention in May and June of 2020, sending weekly SMS and phone calls to parents to deliver lessons in literacy and numeracy. Teräs et al. (2020) discuss experiences in five countries, including three in the Global South (Indonesia, Philippines, and Malaysia), describing approaches to delivering educational content via television and online learning.

Beliefs and Practices for Out-of-School Learning

Parents and families play a crucial role in making choices for how educational resources are acquired and utilized for their children. In order to understand whether and how educational technologies are used to supplement schooling, we must review family involvement in supporting education without technology. Beliefs around the role of families in learning, the practices that families engage in to further their child's learning, and other aspects of these decisions have tended to be wrapped up in a theoretical construct labeled "parental involvement". While the research in this space has tended to refer to parents as primary caregivers and educational deciders, we note that families are complex and multidimensional, and in many contexts around the world the group making choices about a child's education involves a wide variety of community members beyond biological parents (Maynard 2002; Madaio et al. 2019b; Tudge and Hogan 2005; Gregory 2001).

Prior research has outlined a number of dimensions of parental involvement in education, such as expectations about children's school achievement, direct contact with schools, and limits on non-schooling activities in the home (see Fan 2001, for a compilation of indicators). The importance placed on specific dimensions has been shown to vary across cultural groups. For instance, three types of parent involvement—communicating, volunteering at school, and learning at home—were explored in two cultures within the United States, with significant differences across groups observed in which types were valued by the majority of parents in that group (Huntsinger and Jose 2009). In addition, parents' home support approaches showed stability over time, with parents who used formal, structured methods continuing to do so two and four years later.

The history of parental involvement in schools, specifically in rural, low-income, post-colonial African communities, is complex (Hamunyela et al. 2008; Matshe 2014; Simweleba and Serpell 2020). Government administrations have frequently denied parents opportunities to be involved in the decision-making process affecting their children's

lives, because "schools were simply not open to most of our parents" (Samoff 1993). Nonetheless, parents persisted in their efforts.

In Kenya today, many families have taken to sending their children to remedial courses outside of school and during holidays, some of which have even been organized by teachers themselves (Fleshman 2005). Despite government efforts to ban such remedial courses (Omondi 2018), these beliefs are so ingrained in society that parents and teachers have "colluded" to continue organizing remedial courses in secret (Maina and Matara 2018). Similarly, despite private tutoring receiving negative publicity due to inherent inequality of access between members of different socioeconomic classes, parents continue to send their children to receive private tutoring out-of-school, citing that "it is less expensive to pay for private supplementary tuition than to pay the costs of repeating a year" (Chui 2016).

In 2012, MPrep[†] conducted a controlled pilot study of an early version of their SMS-based mobile educational technology, which served as a supplementary study tool integrated into their school schedule. MPrep found that nearly all 30 students studied reported using the platform at home (outside of the regulated study sessions). Moreover, 95% of surveyed parents approved of the platform, with some parents providing weekly allowances to spend on SMS fees (MPrep 2012), consistent with the accounts presented in prior research (Chui 2016; Maina and Matara 2018).

In Côte d'Ivoire, one in three children report reading with their parents at home (Gulemetova et al. 2016), and children with parents who can read were more likely to be reading at grade level and completing primary education (PASEC 2014). Interviews conducted by Madaio et al. (2019b) found that parents supported their children's literacy development at home in a variety of ways, in addition to reading at home, via explicit instruction of pre-literacy concepts, providing educational advice, or connecting students with older family members who could provide instructional support. Moreover, when possible, many parents chose to support their children by "providing resources for learning," which often included pooling their resources with nearby families and paying for private tutoring at home.

Some prior work has also looked at whether parental involvement is affected by school schedule, such as during planned gaps in schooling. This work has been prominently studied in the context of the United States, where schooling typically experiences a months-long break over what is the summer season in the Northern Hemisphere. This long break had its origins at the turn of the 20th century in a growing tendency of urban, wealthier families to leave the city to avoid the summer heat (Gold 2002). In addition to driving the school calendar to meet their needs, wealthier families also possess greater monetary resources to avoid what has become known as the "summer slide", the tendency for children to lose ground in their educational journey when there is a long break in schooling. Wealthier families are better able to afford parental involvement opportunities such as summer schools, camps, and other informal learning activities that extend the learning process during planned schooling gaps (Gershenson 2013). In this work, we specifically look at parent involvement during *unplanned* gaps in schooling. In what ways and to what extent do they engage educational technologies to support their child's learning when school is unexpectedly in recess?

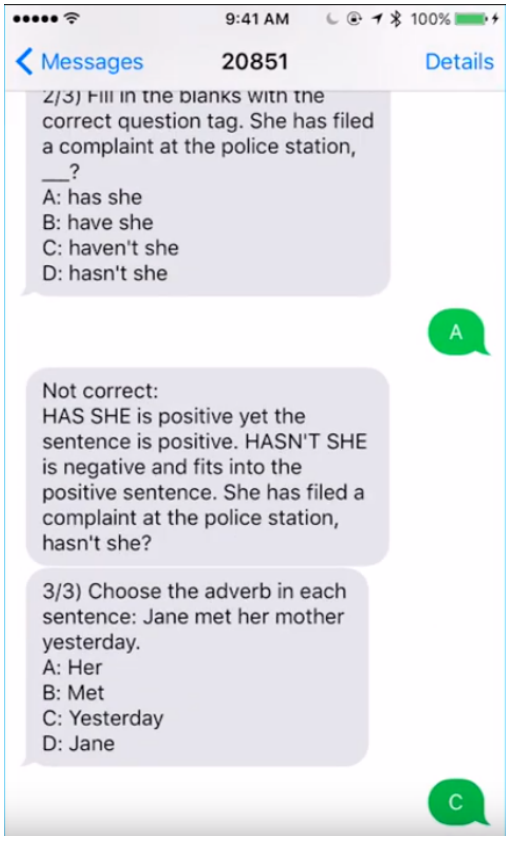

Figure 1. Screenshot of a Shupavu291 quiz question with feedback on English grammar delivered via text message.

Case Study 1: Studying via Text Message during Election Violence in Kenya

In this case study, we examine how students used a popular text-message based mobile learning platform called Shupavu291 during an unplanned disruption to schooling in Kenya. In 2017, just as it did in 2008, the Kenyan presidential election caused large-scale violent protesting and major social disruption, including preventing students from safely attending school (Datoo and Johnson 2013; Kipkoech and Limo 2017; Mbwayo et al. 2020; Roberts 2009). This civil unrest lasted about three months between early August and late October in 2017. Following the victory of the incumbent party in the presidential election on August 8, 2017, the losing party claimed that there was corruption in the voting process, raising tension between the two opposing political parties. The election results were eventually nullified and a re-election slated for October 26, 2017 (Leithead 2017).

The initial election was held during a school break so that school buildings could serve as polling stations. However, civil unrest continued for months and affected access to formal schooling and especially cram schools (commercial after-school programs for test preparation) that are widely

[†]MPrep is now known as Eneza Education, the company that created the educational technology platforms studied in this research.

used. Specifically, schools would adjust class times to let students go during safer hours of the day and many students stopped attending cram school during the period of unrest (J.M. Ishimwe, personal communications, July, 15, 2020). The disruption occurred leading up to the standardized exams in November that mark a major milestone in students' academic progress. Thus, with reduced access to formal schooling and cram schools, students and families sought an alternative mode of study.

The Shupavu291 application is widely adopted among students in Kenya today and its popularity has grown since 2016. As an SMS-based mobile learning application, it is highly accessible even to families who only possess as basic phone. The application and all its learning materials were designed by a group of certified Kenyan teachers who sought to create a study tool that could supplement learning in areas where educational resources are scarce. While Shupavu291 is primarily used by Kenyan students, its reach has expanded to similar products launched by Eneza Education in Ghana and Côte d'Ivoire. The content aligns with the topics and stated learning outcomes of the Kenyan national curriculum for numerous subjects at most levels of primary and secondary education. As of 2019, the platform had 5 million unique learners and offered content tied to 844 distinct curricula, according to its official homepage.[‡] To better contextualize this, we outline the Kenyan school system and curriculum.

The Kenyan education system is structured into eight years of primary school education and four additional years of secondary school education. Schooling has been made free of charge but it is not compulsory. The end of primary school is marked by a standardized test administered nationwide called the "Kenya Certificate of Primary Education" (KCPE) examination. Student performance on the KCPE determines their placement in the secondary school system, which comprises three categories of institutions: state-funded schools, private schools, and *harambee* schools (i.e., partially state-funded). The end of secondary school is marked by another standardized test administered nationwide called the "Kenya Certificate of Secondary Education" (KCSE) (Clark 2015). Passing this test is required to complete secondary school education. The KCPE and KCSE exams test students' mastery of the national curriculum.

Patterns in mobile learning usage, like most other web-based applications, are highly cyclical (Kizilcec and Chen 2020). To understand how Shupavu291 usage changed during the period of disruption in 2017, we examine usage in the surrounding years which includes multiple planned school closures for regular term breaks. In Kenya, the school year is organized into three terms, with a holiday period in between each term. Secondary school students also have a "half-term" holiday in the middle of each term[§]. This case study allows us to address the first two research questions about the potential of educational technology to act as a supplement for formal education during school disruption and how its usage varies between times of disruption relative to periods of normal schooling.

Method

Students can access and sign up for Shupavu291 by dialing "*291#" on their mobile phone using a Safaricom line (the major telecommunication provider in the region). Shupavu291 is primarily marketed via billboards or radio ads, and through word of mouth from friends, family, or teachers. All interactions are via text message (SMS), as illustrated in Figure 1. Students navigate through menus by sending a text message with a number corresponding to a menu item from the options provided in the message they received. After students successfully register for a specific grade level, they may choose from a variety of grade-specific subjects, ranging from "Chemistry" to "Kiswahili." Within each subject, they choose a specific topic and then receive a set of messages containing compact lecture notes and an accompanying quiz (which is generally five multiple-choice questions). Students answer questions sequentially and receive instant feedback on correctness with an explanation. Students can retake any quiz as many times as they like, or use the "Ask-A-Teacher" feature to ask for help and get a response from a teacher working with the platform.

We analyze de-identified Shupavu291 platform log data collected between January 1, 2016 and December 2018. It contains 27,911,108 quiz attempts made by 1,632,504 primary and secondary school students in Kenya. We aggregate these data to the level of weekly activity and compare 2017 (the year when the disruption occurred) to the years 2016 and 2018. Civil unrest started in early August 2017 when schools were closed because of a term break. Between late August and late October 2017, civil unrest in Kenya continued during regular school times.

Our primary measure of usage is the number of weekly active students on the platform; a student counts as weekly active if they attempted at least one quiz during that week. Our secondary measures of interest are the weekly average number of quiz attempts, the weekly average number of courses accessed (e.g., Mathematics and English represent two courses), the weekly average quiz performance in terms of the percentage of correctly answered questions (60% is the passing score for most quizzes), and the time of day that students are active on Shupavu291.

Findings

We first establish a baseline of how students engage with mobile learning over the school year in the absence of major civil unrest. To this end, we examine how many students were active each week of 2018, distinguishing between primary school and secondary school students. Figure 2 shows that spikes in activity coincide with school holidays and leading up to the examination period. Full-term holidays (18 days in April, 18 in August, 30 in December) and half-term holidays (8 days in February and 8 in June) are marked by grey areas. The three-day KCPE and three and a half-week KCSE exam periods are marked by a narrow red and a wide blue area in November.

Secondary school students were particularly responsive to break times, while both primary and secondary school students were engaged before exams. The number of weekly active secondary school students was 61% higher during break periods (the gray bars) than school periods between

[‡] http://shupavu291.com/

[§] https://publicholidays.co.ke/school-holidays/2018-dates/

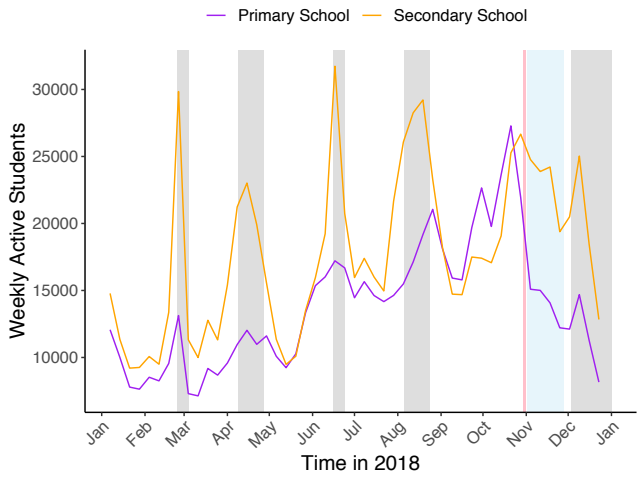

Figure 2. Number of weekly active students using Shupavu291 in Primary and Secondary School. Dark gray bars denote half-/full-term holidays; thin red bar denotes the KCPE examination; light blue bar denotes the KCSE examination.

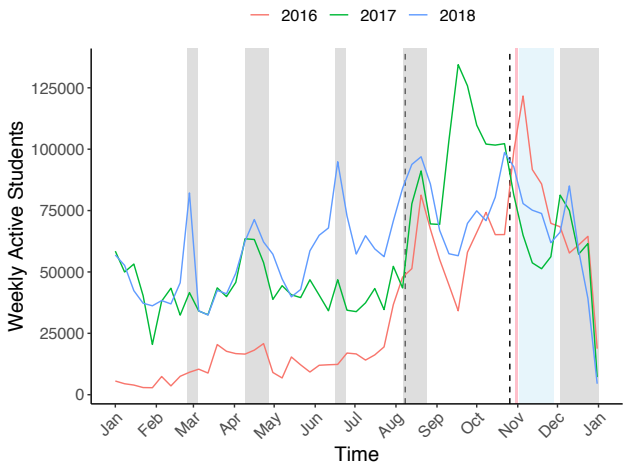

Figure 3. Number of weekly active students in 2016, 2017, and 2018. Gray bars: half-term and full-term holidays. Red bar: dates of KCPE examination. Blue bar: dates of KCSE examination. Left dashed line: date of Kenya's eventually annulled general election. Right dashed line: date of Kenya's re-election. Between the two election dates, more students were active in 2017 than 2016 or 2018.

January and September ($t = 4.196$, $p < 0.001$). In contrast, the same comparison among primary school students yielded only a 5.79% difference ($t = .446$, $p = 0.658$). In the period leading up to the exams (Sep 15–Nov 5), the number of engaged students increased by 86% for primary ($t = 6.201$, $p < .001$) and 56% for secondary school students ($t = 4.482$, $p < 0.001$). Engagement among primary school students dropped sharply during and after the brief KCPE exam period (the red line), while secondary school students remained engaged during most of the KCSE exam period (the blue bar).

Given this insight into the character of a typical mobile engagement pattern, we proceed to compare engagement in 2017 (the year with civil unrest) to engagement in 2016 and 2018. In Figure 3, we observe the same outcome measure, the number of weekly active students, combining primary and secondary school students for ease of presentation and because findings are qualitatively similar for both groups. The period of civil unrest in 2017 is marked by two dashed lines, which indicate the original election date and the rescheduled election date.[¶] As is clearly visible in the figure, the number of weekly active students during that period was 52.9% higher in 2017 than in 2016 and 2018 ($t = 2.6881, p = .0175$), an average absolute difference of $91,001$ students per week. This shows that students increasingly sought out mobile learning during the disruption of normal schooling, which addresses our first research question.

To further investigate how mobile learning use differed during the unplanned school closure from periods of normal schooling (RQ2), we examine multiple indicators of how students learned: quiz effort, quiz performance, course variety, and their study schedule. We compare outcomes in 2017 to 2016 and 2018 using the same visualization approach for all but the last measure.

We find that as more students became active, the average active student attempted fewer quizzes per week as time went on during the period of school disruption (Figure 4), from 4.14/week in mid-August down to 2.27/week in mid-October. Nevertheless, the average number of weekly quiz attempts during the period of civil unrest was similar in 2017 (3.06/wk) and in 2016 (3.21/wk; Tukey's HSD $p = 0.834$), but marginally lower in 2018 (2.40/wk; Tukey's HSD $p = 0.037$) for the same period (one-way ANOVA $F_{2,30} = 5.7218, p = 0.0079$). In relation to the rest of the year 2017, the average number of quiz attempts is lower during the disruption, which could reflect the influx of new users, some of whom may just be trying out the application.

Students' quiz performance, measured in terms of the average percentage of questions students answer correctly, remains relatively steady over the period of disruption (Figure 5). The exception is a dip in performance that coincides with the spike in the number of weekly active students in 2017. Compared to normal school times in 2017, the quiz performance is 3.4% higher during the disruption, but the onset of this increase in mid-July predates the period of disruption and is mirrored in 2018. Compared to 2016, quiz performance during the period of disruption is higher in 2017 (95% CI: $[0.0319, 0.0337]$, $t = 68.777$, $p < 0.001$) but lower in 2018 (95% CI: $[-0.0202, 0.0184]$, $t = -42.457, p < 0.001$).

Students' course variety, which is the number of different courses they accessed, decreases sharply throughout the period of disruption (Figure 6). In contrast, course variety remained constant during the same period in 2018 and even increased in 2016. This suggests that during the period of disruption in 2017, students may have shifted their focus from exploration to studying specific subjects for the upcoming exams. In 2017, students' average course variety was also 17.0% lower during the disruption compared to normal periods of schooling.

[¶] https://en.wikipedia.org/wiki/2017_Kenyan_presidential_election

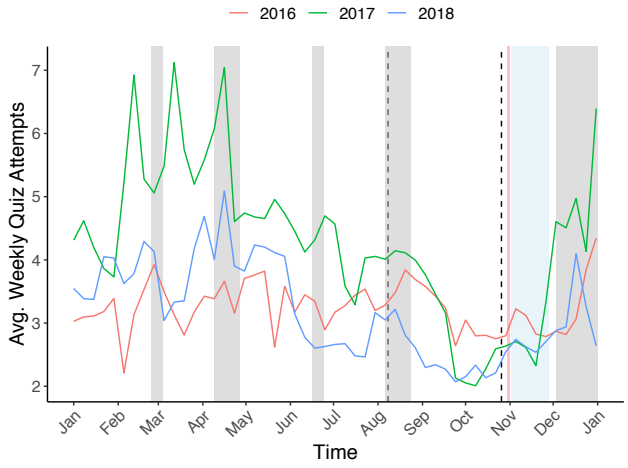

Figure 4. Number of weekly quiz attempts in 2016, 2017, and 2018. Dark gray bars denote half-/full-term holidays; thin red bar denotes the KCPE examination; light blue bar denotes the KCSE examination. Left dashed line denotes the eventually annulled general election; right dashed line denotes the re-election.

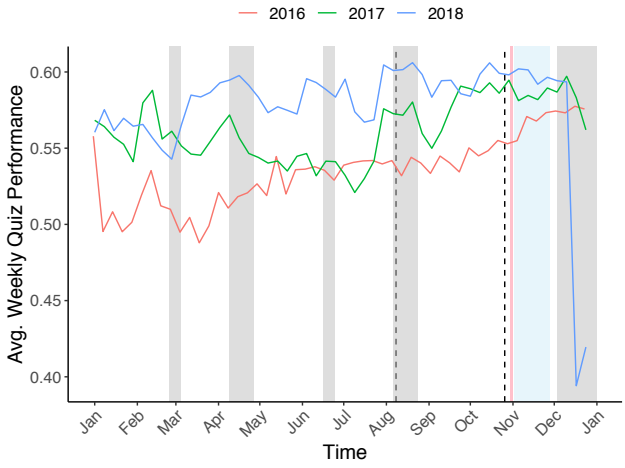

Figure 5. Average quiz accuracy on first attempt in 2016, 2017, and 2018. Dark gray bars denote half-/full-term holidays; thin red bar denotes the KCPE examination; light blue bar denotes the KCSE examination. Left dashed line denotes the eventually annulled general election; right dashed line denotes the re-election.

The disruption may affect when students spend time studying in school or cram school compared to using mobile learning. We investigate variation in students' daily mobile study schedules during the period of disruption, based on how quiz attempts are distributed over the hours in day (Figure 7). In 2017, students were most active on the platform after school and into the evening hours. We find that students' study schedules during the period of disruption in 2017 are different from those during the same period in 2018 (Kolmogorov–Smirnov $D = 0.0277, p < 0.001$), with students activity on Shupavu291 shifting to slightly earlier in the day in 2017. Surprisingly, study schedules in 2016 are remarkably different from those in 2017 or 2018 (KS $D = 0.1313, p < 0.001$), with a bimodal distribution that shows an additional spike in activity during school hours. This earlier usage in 2016 is not an artifact of a few days of activity but a consistent trend in 2016 that suggests that Shupavu291 usage was different then: teachers may have incorporated mobile learning into their classroom routines.

Discussion

In Kenya, it has long been common for parents and teachers to encourage children to attend after-school remedial coursework and private tutoring when affordable (Fleshman 2005; Omondi 2018; Chui 2016). However, during the period between the two elections, during which there were many violent and non-violent protests (Leithead 2017), schoolteachers encouraged students to return home as early as possible to avoid violence (J.M. Ishimwe, personal communications, July, 15, 2020). During this period, we find that more students opted for mobile learning through Shupavu291, compared to the same period in 2016 or 2018. The 53% increase in active users provides clear evidence that educational technology was acting as a supplement for educational access during this unplanned gap in schooling (RQ1). This response to disruption may come naturally to students who already exhibit a strong pattern of using mobile learning during times of school breaks. Moreover, the disruption occurred leading up to high-stakes exams which creates competitive pressure for students to find ways to continue their studies.

During the time of disruption, we not only observe increased demand for mobile learning, we also see changes in how students used Shupavu291 (RQ2). In particular, with an influx of new users, the average student engaged with fewer quizzes per week during the disruption than during periods of normal schooling. However, students still took the study materials seriously, as evidenced by the relatively constant rate of quiz performance during the period of disruption. Students become more focused in their studies during the disruption and worked on just one or two different courses (subjects) on average. This reduction in course variety may also reflect the influx of new students who engage with fewer quizzes on average and therefore have fewer opportunities to try different courses. Finally, we saw only a small shift in students' study schedules during the period of disruption. This is consistent with the theory that students use Shupavu291 as a low-cost alternative to cram schools, as suggested by the fact that most activity occurs after school hours. The rise in active users may be driven by students who typically attend cram school during that time of day, but opted for the safer mobile learning option during the period of disruption. Student activity on Shupavu291 was shifted to slightly earlier in the afternoon, which may suggest that students returned from school earlier and started mobile learning at home.

Overall, we find that students are adaptive in their study strategies and move swiftly to mobile learning as a supplement to formal schooling during times of disruption. When attending in-person tutoring and remedial coursework may not be a safe option, affordable mobile learning may serve as a desirable and accessible alternative, especially leading up to high-stakes exams. While prior work on mobile learning in this context has raised concerns about the high rate of student attrition (Kizilcec and Chen 2020), the present findings provide a more optimistic perspective on the role of

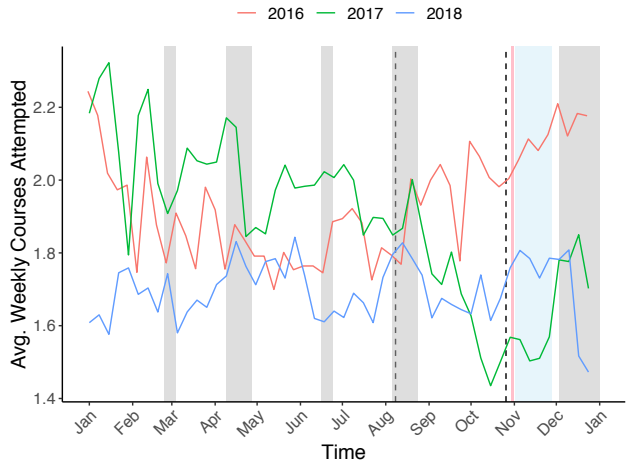

Figure 6. Weekly average number of courses accessed in 2016, 2017, and 2018. Dark gray bars denote half-/full-term holidays; thin red bar denotes the KCPE examination; light blue bar denotes the KCSE examination. Left dashed line denotes the eventually annulled general election; right dashed line denotes the re-election.

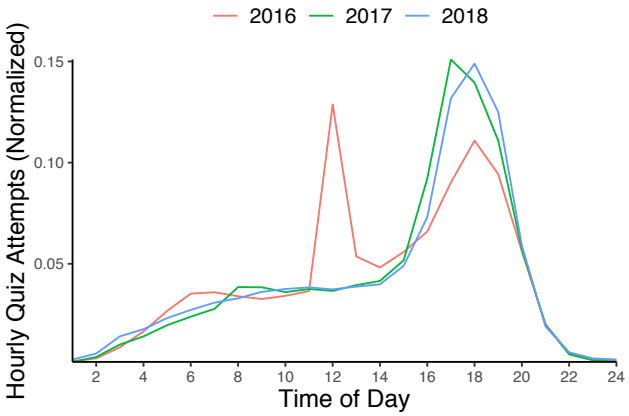

Figure 7. Proportion of hourly quiz attempts in 2016, 2017, and 2018 during the period of civil unrest due to election violence.

mobile learning during times of civil unrest. Given the wide age range of students on Shupavu291, this also suggests that families are inclined to adopt mobile learning technology to support their children's learning during periods of disruption.

Case Study 2: Early Literacy Learning during Teacher Strikes in Côte d'Ivoire

In this case study, we examine how families in rural Côte d'Ivoire used a voice- and SMS-based mobile learning technology called Allô Alphabet during a sustained period of school closures due to teacher strikes.

In Côte d'Ivoire, nationally organized teachers' associations, such as the *Syndicat National de la Recherche et de l'Enseignement Superieur* (SYNARES) and the *Syndicat National de l'Enseignement Secondaire en Côte d'Ivoire* (SYNESCI), have wielded significant political influence in postcolonial Ivorian society. They represent an organized professional class of significantly larger size than other professional associations such as doctors, lawyers, and journalists (Woods 1996). Throughout the 1970s, teacher associations formed the backbone of much political resistance to the Houphouet regime, which came to a head in 1982, as teachers mobilized in strikes in part to protest the national government's intended rollout of an expensive educational TV program (Woods 1996). This program was met with widespread resistance from parents, teachers, and teachers' associations, who saw the national investment in educational television as a political move to defund and disempower teachers. The organized resistance to investment in educational television (at the expense of investing in teachers' salaries) led to the first nationwide teachers' strikes in Côte d'Ivoire (Woods 1996), a precursor of subsequent organized industrial actions (including strikes) from Ivorian teachers over the next 40 years.

For this case study, after a series of recent strikes in schools in the south-central Lacs region in 2019, COSEF, a coalition of eight teachers' unions, launched an indefinite strike in public elementary and secondary schools around Côte d'Ivoire beginning on January 22nd, 2019. COSEF demanded an increase in teachers' housing allowances, a formal cancellation of courses on Wednesdays in primary schools (an informal practice in many village schools already), and the payments of arrears of salary of the teachers, while demanding better living and teaching conditions[‖]. It is difficult to get an accurate estimate of the number of institutions closed during the strike due to disputed sources of data. The teacher coalition claimed that 98% of primary and secondary schools were closed, while the Ivorian Ministry of Education claimed only "about half" or "only a few pockets" were closed, as of March, 2019 [**]. On March 19th, 2019, the teacher coalition reached an agreement with the Ministry of Education that their demands would be reviewed by a commission, and teachers imprisoned during the strike would be released. Schools were officially reopened on March 25th, 2019, after just over 2 months of striking.

Prior to the strikes, Eneza Education had opened an office in Abidjan, Côte d'Ivoire, where they were preparing to launch a version of their Shupavu291 platform in Côte d'Ivoire. Madaio et al. and Eneza Education designed a new mobile learning technology, Allô Alphabet, to target younger children with gaps in fundamental literacy skills in rural Ivorian communities. Unlike the target user group for Shupavu291, the students targeted in this work would likely not have sufficient literacy skills to read SMS messages (PASEC 2014).

Allô Alphabet was designed to use an interactive voice response (IVR) system to deliver voice-based lessons and quizzes to foster early literacy skills such as phonological awareness, combined with SMS messages introducing letters later in the curriculum, accessible on low-cost mobile devices (Madaio et al. 2019b,a). During a 4-month longitudinal deployment of Allô Alphabet in 16 schools in 8 villages (Madaio et al. 2020), teachers went on strike for nearly 2 full months (with 6 of the 8 weeks of the strike overlapping with the beginning of the study). While

[‖] https://bit.ly/2pmAjjw
[**] https://bit.ly/2VGPyQz

Figure 8. A parent helps his child use the voice response literacy system.

Allô Alphabet was designed to be an at-home learning intervention, it was not clear how such a long period of school closures due to the strike would impact families' adherence to a learning intervention.

Thus, to understand how educational technologies may be able to supplement formal instruction during periods of school disruption, we analyze quantitative call log data from children's use of Allô Alphabet in the period during the teacher strike compared with the period of normal schooling following it. We supplement these analyses of log data with qualitative data from interviews with families during and after the strike to understand whether, how, and why, they think their children *should* continue learning (with an educational technology) during the strike, and then how they *did* use Allô Alphabet during the strike (Figure 8).

Method

To help address low child literacy rates in Côte d'Ivoire (PASEC 2014; Lucini and Bahia 2017), Madaio et al. designed and implemented an early literacy curriculum using interactive voice response (IVR), Allô Alphabet (Madaio et al. 2019a,b, 2020). Literacy development is supported by many cognitive and linguistic skills including phonological awareness (i.e., the understanding that language consists of patterns of sound combinations) (Kurtz 2010). Allô Alphabet thus targets French phonological awareness and print-sound mapping, gradually increasing in complexity and difficulty, from simple phoneme and syllable awareness, to mappings between letters, words, and sounds. The system provides instructions, questions, and feedback via voice messages recorded by an Ivorian speaker, with answers input via touchtone. When the users call the IVR, the system plays a welcome message, updates the user on their progress, and selects the next lesson based on the user's prior mastery of concepts. Each lesson begins with an explanation of the concept in that lesson and an explanation of how to respond. For each question, the system plays a prerecorded audio message with the question and response options. After responding, students receive feedback on their responses. If incorrect, they receive the same question, with a hint explaining the concept or prompting the student to focus their attention on a particular part of the word or syllable.

Here, we analyze log data from the 234 children who called to access the system, including data on the frequency of calls, the length and timing of calls, and data on children's performance on the lessons. To obtain the qualitative data, one of the authors (an HCI researcher), together with a linguistics graduate student at an Ivorian university who spoke several local mother tongues, visited 40 participants at their homes: 15 in the first month of the study, and 25 in the final month of the study. We wanted to understand how families might use an educational technology at home during the strike, and so we conducted semi-structured interviews with parents and other caregivers about their perceptions of the strike, whether and how children typically learn during a strike, and whether and how they believed their children would use Allô Alphabet during the strike.

To understand the most salient themes in our qualitative data, we adopt an inductive thematic analysis approach for qualitative data analysis from Braun and Clarke (2006). We engaged in four primary levels of analysis of the data: beginning with open coding of the raw data, then generating axial codes that capture a more abstract representation of the data, then organizing those axial codes into a set of categories, which, finally, are summarized by "core categories" (Strauss and Corbin 1990), such as parents' beliefs about literacy, families' mobile phone usage, parents' relationship with the local schools, and more. As this is designed to be an iterative process of sense-making from data, we went through the coding process and discussed the emerging themes, synthesizing the emerging codes as necessary to arrive at what is referred to as theoretical saturation, or the point at which the data is fully described by the codes (Strauss and Corbin 1990). Throughout the data collection process, we conducted regular debrief sessions with interpreters and others from the Adzopé region to help resolve questions about concepts that arose during the interviews and validate the emerging themes (following Brown et al. (2002)).

Findings

Educational technology usage during the strike We used the system log data to examine whether and how students in the study continued learning during the teacher strike. Specifically, we used Allô Alphabet log data to understand how students' use of the system differed in the six weeks of the teacher strike compared with the other nine weeks of the study when school was in session.

First, we investigate whether there were differences in the amount that students accessed Allô Alphabet, by calling in to the interactive voice response (IVR) platform. Although we expected to see lower usage rates during the strike, given the

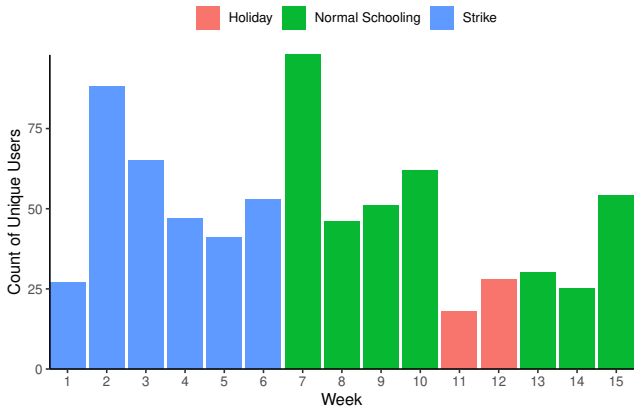

Figure 9. Number of unique users calling the IVR during the study, during the strike, Easter holiday, and normal schooling periods.

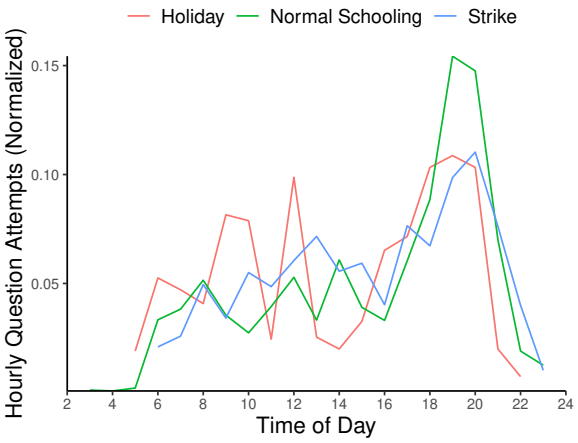

Figure 10. Proportion of hourly IVR calls during the strike, holiday, and normal school periods.

disruption to schooling (cf. Abadzi 2009), we did not find a significant difference in the number of students calling in per week during the strike than during the school period (mean = 54 vs. 52; Kolmogorov-Smirnov $D = 0.19$, $p = 0.99$). The number of calls students made to the IVR was also not significantly higher during the school period than during the strike (mean = 4.2 vs. 3.3; $D = 0.11$, $p = 0.26$). That is, roughly the same number of students were accessing the IVR during the strike, and they were calling roughly the same amount as during the school period.

Next, to investigate differences in the literacy lessons completed by students, we focus on the length of time students spent on the calls, the total number of questions they attempted, and their average correctness on those questions. We find that, on average, students spent more time using Allô Alphabet during the strike (m=126 seconds, sd=376.8s) compared to during the school period (m=99s, sd=273.2s; $D = 0.04$, $p < 0.001$). In addition, perhaps as a result of that greater amount of time spent using the system, students attempted more questions during the strike on average (m=55.9, sd=42.2, med=50) than during the normal school period (m=51.8, sd=38.3, med=36; $D = 0.12$, $p < 0.001$). However, there was no difference in the average correctness of these questions ($D = 0.01$, $p = 0.90$).

During the two-week Easter holiday, we found no significant difference in the number of students who called Allô Alphabet relative to the normal schooling and strike periods ($D = 0.85$, $p = 0.17$). There was also no significant difference in the average number of calls each student made per week over Easter (mean = 4.7 vs. 4.2; $D = 0.11$, $p = 0.95$). However, students spent less time on the lessons over Eastern than when school was in session (mean = 75s vs. 99s; $D = 0.04$, $p < 0.005$), and perhaps as a result, students also attempted fewer questions (mean = 42 vs. 52; $D = 0.17$, $p < 0.001$). However, the average correctness during the Easter holiday was higher than during the period of normal schooling (0.54 vs 0.48; $D = 0.05$, $p < 0.01$).

As in the Kenyan case study, we wanted to understand how the disruption to schooling relates to the time of day that students were accessing lessons. We found significant differences in the time of day students use Allô Alphabet, with students attempting questions later in the day during normal schooling, compared to during the strike or holiday periods (median = 5:00pm [normal] vs. 4:00pm [strike] vs. 3:00pm [holiday]; ANOVA $F_{2,12145} = 57.5$, $p < 0.001$). Figure 10 shows the distribution of call times during each of the three periods.

Family beliefs about learning during a strike In the interviews with families participating in the study, we find that parents and other adults believe that (1) teacher strikes prompt a shift in responsibility for children's education from the state to the family; and that (2) children should continue studying and learning during the strikes; but that (3) parents and other adults felt unable to enforce their children's learning during a strike. Some families expressed hope that Allô Alphabet could support the continuity of learning during a strike.

Parents strongly believed that the national teacher strikes — of which this was just the latest in a long series of strikes over the last several decades (Woods 1996) — had negative repercussions for their children's education. Several parents told us how bad the strike was for their children, saying, "*I pray to God the strike must stop. My wish is that it will end, and afterwards, the children will go to school again.*" (P26) The most common concern that parents had was that the strike would "*make children late*" (P7) in their educational development, or delay their progress. This language of the strike making their children "late" was echoed almost verbatim by 5 families (P1, P7, P18, P22, P36). One parent elaborated, saying that during the strike, the child will "forget everything they have done", and they thus needed more repetition in order to remember it (P1).

Parents suggested the strikes precipitated a shift away from the state's responsibility for children's learning, saying "*[The strike is] a handicap for Côte d'Ivoire. Now the State of Côte d'Ivoire is turning away from the conditions of the institutions here.*" (P13). This parent, who also happened to be a teacher, and the president of the school-community association (Comité de Gestion d'Écoles, or COGES), believed that the state was "turning away" from the local conditions in their village. Another family ember explicitly described this shift in responsibility for education from the

state to the family, saying "*it is now up to the parents to be vigilant so children don't abandon their studies*" (P34).

Parents felt their children should continue learning during the strike. Some parents told us how they hoped the system would allow their child to continue doing exercises even when the parents were not home. Before the study started, one father told us how "*If there is a strike, even on vacations, you must always read and learn something*" (P29). Another family member told us how Allô Alphabet would "*allow many students to study, because with the phones, when the parents are traveling, they can always call and do lessons by message to study. It will allow him to progress*" (P10). Others told us that they would tell their child to use Allô Alphabet "*If you have some time to call during the day*" (P28). One parent told us that, "*She must continue to exercise when she is not at school. Normally, during summer vacation the child goes to summer lessons. Now, when we go to the field, the phone could work like that — like she's at the summer lessons*." (P20).

However, parents felt unable to enforce their children's learning during the strike, due to their work or travel (e.g., traveling to the cocoa fields or other nearby villages). Parents told us that, before the strike, older siblings who are still in school would help the child when parents were working, but "*once the strike started, the older brothers have gone to the field [camp]*" (P11). In fact, during the strikes, it's not only the older male siblings who go to the field, but, as that mother elaborated: "*during long strikes, most parents take their children to the field*" (P11). Other parents told us how, because of the unpredictability of the duration of the strike, they felt that their children who are still of school age needed to remain in the village in case school starts again, saying "*if the teachers are on strike today, tomorrow it can stop. If I send them to the camp, and there is school tomorrow, how am I going to know? Sometimes when you are in the bush the phone calls do not go through*" (P19). For some parents, when their children remained in the village during the strike, they hired private tutors to help continue their children's learning. Some families had paid for these tutors throughout the year, while others hired them specifically for the strike period. In some cases, the tutors were even the teachers, themselves. "*[The tutor] is normally his teacher at the school, and he is now the one who teaches them during the strike. My son goes to the gentleman's house. He takes four or five students at a time for lessons*" (P22).

However, a smaller number of parents felt that learning during the strike is up to the child's choice. One parent told us, "*it depends first of all on the child. If he is self-aware, and if he wants to study*" (P17). They went on to explain this with an example of the child being responsible for decisions about their hygiene, saying, "*I'm not going to force you to wash, be clean, stuff like that*" (P17). However, during the strike, this parent told us, "*Since now there is the strike, you do not see [my son] anymore*" (P17). Other parents described how children felt empowered to do what they wanted during a strike, saying:

> *When there is a strike, the children are all happy. They say: 'Yes, we won! We can go play and do anything.' Dad can not do otherwise. I can try to say, 'Come and read.' But he will say, 'There is a strike, we have been left alone, what do you want?'* (P23)

This feeling of resignation from this parent was due in part to the father leaving the village to work at the field during the day, or for several days at a time. When they left, they did not feel that they could properly supervise their children during the strike. In fact, at the endline, when we asked parents whether their children had actually used Allô Alphabet to learn during the strike, most were unable to say for sure. One older sibling did tell us how, during the strike, their sister was home and "*most days, when I'm babysitting, she comes to ask me [to use Allô Alphabet]*. I was surprised that she came to ask me for it." (P34). However, most other parents echoed the previous father's frustration in not being able to control children's behavior when school was out of session and parents were working.

Discussion

School closures due to teacher strikes in Sub-Saharan West Africa generally (Abadzi 2009) and Côte d'Ivoire specifically (Woods 1996) are a frequent occurrence. Here we investigated whether and how a voice-based educational technology, Allô Alphabet, might supplement formal schooling during one such teacher strike in 2019. During a planned 15-week deployment of Allô Alphabet, the occurrence of a teacher strike for six of those weeks presented the opportunity for a natural experiment to understand children's use of the system during the strike compared to the rest of the school period.

We find that parents describe strikes as prompting a shift in the state's responsibility for children's education to the family's responsibility, causing delays in children's educational development and risking that children forget what they had learned (Cooper et al. 1996). To compensate for this, some parents describe *wanting* their children to continue learning at home during the strike, but with many parents' farm work taking them out of the village for days or weeks on end, they felt unable to effectively ensure children are continuing to learn, with some parents appearing resigned to the idea that children will do what they want during the strike, be that play, study, or, they hoped, use the system to do literacy lessons.

Despite the sustained closure of formal schools — and parents' admission in the interviews that they were unable to monitor and regulate children's learning during the strike to the extent that they wanted — we did not find significant differences in usage of Allô Alphabet during the strike compared to the period of normal schooling. While parents were unable to tell us for certain whether or how their children were using Allô Alphabet at home during the strike, we saw in the log data that, in fact, the system use was roughly equivalent during the strike and the normal school period. We did find that during the strike, children accessed Allô Alphabet at more evenly distributed times throughout the day (as they are not in school), and they accessed the system for longer periods of time, per session, attempting more questions than they did when using the system during the period of normal schooling. In contrast, during the Easter vacation, children spent less time using Allô Alphabet and answered fewer questions, which reinforces the idea that

unplanned disruptions are treated less like a break from schooling than planned gaps in schooling like a holiday.

These results suggest that, in spite of challenges for adults' availability to supervise and support learning with educational technology during sustained school closures, educational technology can supplement gaps in formal instruction. These findings also suggest that there may be additional opportunities for educational technology to foster asynchronous support from family members who may be working during the day while the child is learning with the educational technology, but who still want to be involved in their children's learning. In addition, given that children may have more autonomy over choosing to use educational technology to supplement learning during school closures, such systems should provide support for children's self-directed or self-regulated learning. Finally, given the historical legacy of teacher strikes motivated by educational technology deployment (e.g., educational TV) in Côte d'Ivoire, care should be taken to further understand teachers' perceptions of educational technology use during strikes, to ensure their well-being and political aims are not subverted in service of student learning.

General Discussion

Educational technology is often touted as a vehicle for expanding access to education and overcoming barriers to schooling in low-resourced parts of the world. The last two decades have shown that, in practice, it is a more complex enterprise to support learning with technology than to simply make it available to students (Ames 2019; Cuban 2018; Reich 2020). Creating the conditions under which technology can be an effective study aid can be costly and time-consuming to establish: procuring technology, teacher professional development, and training students, to name but a few. In contrast, this study focused on the role of an already ubiquitous technology (i.e., feature phones) during unexpected disruptions of formal schooling, which are common occurrences for schoolchildren in Sub-Saharan Africa. Specifically, we presented two new case studies examining the extent to which mobile educational technology acts as a supplement for educational access during unplanned gaps in schooling (RQ1). We further explored how students used mobile technology differently during the disruption than periods of normal schooling (RQ2), and their families' beliefs and practices around technology (RQ3).

The two case studies answer these research questions from complementary perspectives. The first study took place in East Africa with 1.6 million mostly urban and suburban primary and secondary school age students. The second study took place in West Africa with 750 rural primary school students. The educational technology in the first study relies entirely on text messaging, while the second is based on an interactive voice response with text messaging. The unplanned disruption is due to an outbreak of election violence in the first study and due to an organized teacher strike in the second. Both case studies allowed us to draw comparisons to holidays as planned periods of school disruption, and examine the role of technology with respect to informal schooling like cram schools and private tutoring. While the Kenyan case study lacks a qualitative understanding of student and family experiences with technology during the disruption, it features one of the largest samples in the mobile learning literature. The Ivorian case study involves a smaller sample, but its on-the-ground interviews provide a rich understanding of the student and family experience. Taken together, the case studies therefore complement each other to strengthen the empirical support for our conclusions.

We found strong evidence that educational technology acted as a supplement to formal schooling in both case studies. At least two contextual factors are likely to have contributed to this outcome. First, the barrier to using the technology was extremely low: text messaging is affordable in Kenya, and families incurred no cost in the Côte d'Ivoire study. Second, students and their families had reason to trust the application: Shupavu291 was already widely used and Allô Alphabet was provided by a team of American and Ivorian researchers, in partnership with the Ministry of Education and local village leaders. The ease with which students and their families were found to adopt mobile learning during the disruption speaks to its accessibility. In the absence of unplanned disruptions, students used mobile learning primarily during school breaks, suggesting that many families were already familiar with mobile learning and its uses prior to the disruption. Compared to periods of normal schooling, students engaged in mobile learning on a similar schedule and with equivalent effort and performance during the disruption. It demonstrates the willingness of families to use educational technology to supplement schooling under the right conditions.

Our research questions focus on the disruptions to formal schooling, but in the process of conducting this research it became apparent that educational technology interacts with a more complex educational ecosystem. Many families in Kenya and Côte d'Ivoire hire private tutors, send their children to cram schools, or provide their own familial instruction (Chui 2016; Fleshman 2005; Omondi 2018; Maina and Matara 2018). This system of informal schooling was disrupted during the period of election violence and civil unrest in Kenya as it was unsafe for students to be outside late in the day (J.M. Ishimwe, personal communications, July, 15, 2020). This manifested in an increase of Shupavu291 usage after school. In the Ivorian context, formal schools closed during the strike leading families to rely more on private tutors and to use Allô Alphabet more consistently throughout the day. Thus, educational technology can supplement both formal and informal schooling, depending on the type of disruption and prevailing norms around informal learning.

Educational technology use during periods of planned disruption, such as mid-term and holiday breaks, emerged as helpful points of comparison to periods of unplanned disruption. In the Kenyan case, term break periods saw a remarkable spike in mobile learning. In this way planned disruptions unwittingly give students and their families the opportunity to learn what they might do during an unplanned disruption. Students and their families may already have identified a suitable mobile learning application and created an account, and they have a relationship with a summer tutor who can be approached for ad-hoc tutoring during the period of unplanned disruption. Nevertheless, a crucial

difference between planned and unplanned disruptions is the uncertain duration of school closures. The amount of private tutoring needed for extended disruptions is not sustainable for some families who may resort to mobile learning as a more feasible, albeit less intensive, supplement.

Educational technology assumes a particular role in the ecosystem not only because it tends to be more affordable than private tutoring or cram school. Parents who are keen to understand their children's academic standing can talk to a tutor but not a mobile app. This personal relationship can help them build trust in a way that is hard to replicate with a mobile application. Our interviews with Ivorian parents highlight that families wish to be involved with their children's mobile learning, but they may not have the time or the digital literacy to achieve this. We therefore identify the need for educational technology to communicate students' academic achievement to families as a ripe area for further development and research.

We report both case studies to complement the limitations of one with the strengths of the other. Although both studies are observational accounts centered around exogenous shocks to the education system, we do not attempt to make causal claims, nor do we have evidence of learning gains after using the systems. The Ivorian case study was originally designed as a randomized controlled trial to test the efficacy of Allô Alphabet in improving learning outcomes. We had randomly selected half of the schools in each of the eight participating villages for students in the CM1 grade to be recruited to either the treatment condition (i.e., given a phone with access to Allô Alphabet) or control condition (i.e., business as usual). Both groups were given a pre-assessment based on the internationally validated Francophone EGRA assessment (International 2009), and we provided both groups an isomorphic post-assessment at the end of the 15-week study. However, prior to distributing the phones to participating families, a law was passed in Côte d'Ivoire requiring all SIM cards to be registered to individuals, using government-issued photo IDs. We encountered significant challenges successfully registering the SIM cards, including participants not having caregivers with a government-issued photo ID. These problems only became fully apparent several weeks or months into the deployment. Thus, over 400 participants were not able to have their SIM cards successfully registered and could not access the IVR, impacting participation rates and leading to reductions in power that prevented us from conducting evaluations of learning gains.

These sociopolitical factors (including the SIM registration law, but also the teacher strikes) are a common feature of many educational ecosystems around the world. They are likely to obstruct future randomized controlled studies designed to assess the efficacy of educational technology. This may partly explain why rigorous studies that evaluate learning outcomes are generally rare for deployments of educational technology in developing contexts. To assess the impact of educational technology on student outcomes, future research could explore the possibility of linking mobile learning records to standardized test results, such as the KPSE or KCSE in Kenya.

Conclusion

We are left with the fundamental question of whether educational technology has a positive or a negative impact on families. In a world where schools are adequately resourced and not subject to unplanned disruptions, families would receive sufficient academic support from formal schooling. However, the reality in many developing contexts, and especially in Sub-Saharan Africa is a different one. Schools are frequently disrupted, there is a shortage of teachers, and families are already resorting to a wide range of informal schooling options, some of which teachers and families may find in conflict with their own educational goals. Educational technology appears to be entering into a complex ecosystem of informal learning that exists as a resource to families. Our findings show that educational technology serves as a supplement during times of school disruption, but when, where, and for whom it is effective compared to formal schooling or other types of informal schooling remains an open question.

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