Collective Support and Independent Learning with a Voice-Based Literacy Technology in Rural Communities

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ABSTRACT
Access to literacy is critical to children's futures, but formal education may be insufficient for fostering early literacy, especially in low-resource contexts. Educational technologies used at home may be able to help, but it is unclear whether or how children (and families) will use such technologies at home in rural communities, particularly in low-literate families. In this paper, we investigate these questions with a voice-based literacy technology deployed with families in 8 rural communities in Côte d'Ivoire for 4 months. We use interviews and observations with 37 families to investigate motivations, methods, and barriers for rural families' engagement with a literacy technology accessible via feature phones. We contribute insights into how families view digital literacy as a learning goal, leverage networks of supporters, and over time, transition from explicit to implicit support for children's learning.

Author Keywords
HCI4D; ICTD; educational technology; literacy; IVR

CCS Concepts
•**Human-centered computing** → **Collaborative and social computing;** *Field studies;* •**Applied computing** → *Education;*

CHI '20, April 25–30, 2020, Honolulu, HI, USA.

ACM ISBN 978-1-4503-6708-0/20/04 ...$15.00.
http://dx.doi.org/10.1145/3313831.3376276

INTRODUCTION
Access to literacy is critical for unlocking opportunities for children's future educational attainment and economic outcomes [30], as well as providing access to what Amartya Sen calls "the opportunity for people to live lives they have reason to value" [77]. However, despite an overall rise in global literacy rates, these gains have not been evenly distributed, and rural regions in low-resource contexts have lagged behind the global average [72]. Educational technologies may help supplement gaps in schooling in low-resource, agricultural contexts [15, 54], but such technologies are typically used primarily at school [62, 85]. In contexts where children may be missing school for farm labor [66], these systems may need to be used at home. The home environment is critical to supporting early literacy [44, 78], but in contexts with low adult literacy, as in some regions in Côte d'Ivoire [66], it is not clear whether or how families may support children's literacy at home.

Through multiple studies in a research program over the last several years, we investigated families' methods for supporting literacy at home and their design needs for literacy support technology [51]. Using these findings as design guidelines, we developed an interactive voice response (IVR) literacy system for fostering French phonological awareness and deployed it in a preliminary study in one village in rural Côte d'Ivoire [50]. Then, to investigate how and why children and their families adopt and use such a system over several months at their homes, we deployed our IVR system, Allô Alphabet, with 750 families in 8 rural communities in Côte d'Ivoire for 4 months. In this paper, we use survey data from this 4-month study and qualitative interviews with 37 participants' families to investigate motivations, methods, and barriers for family engagement with our literacy technology over time.

We found that (1) parents valued children developing digital literacy as an important skill in its own right, but parents were concerned about children using mobile devices on their own; (2) parents recruited other family members to support children's system usage when parents were unavailable or lacked fundamental skills to support in explicit ways; and (3) over the four months of the deployment, family supporters transitioned to more supervisory, monitoring roles, fostering children learning more autonomously. These findings represent contributions at the intersection of HCI and information-communication technology for development. We contribute implications and design opportunities for educational technologies deployed with families in rural contexts: designing for (1) digital literacy skill acquisition; (2) distributed, collective networks of technology supporters; and (3) negotiated autonomy in learning with and about technology.

RELATED WORK

Literacy education in low-resource agricultural contexts

Access to literacy is critical for unlocking opportunities for children's future educational attainment and economic outcomes [30]. However, despite an overall rise in global literacy rates, these gains have not been evenly distributed [72]. The contributors to low childhood literacy rates are complex, including factors across the home, school, and community ecosystem [66]. In rural areas in Côte d'Ivoire, as in other low-resource contexts, children who participate in agricultural work are less likely to complete primary school due to interruptions in schooling and are less likely to be literate [66]. Although 94% of Ivorian primary-school-aged children were enrolled in primary school, only 61% completed it [66].

Prior research has shown that a stimulating home literacy environment is a critical driver for children's early literacy [44, 45, 47, 78], but in contexts where adult literacy is low, children may lack critical support for literacy at home. In Côte d'Ivoire, 53% of men and 33% of women read at an age-appropriate level, with large differences between rural and urban regions [49]. Prior research suggests that parents may foster early literacy by providing dispositional support by communicating the value of literacy-building behaviors [8], motivational support for learning [44, 63], metacognitive support for maintaining children's attention and scaffolding self-regulated learning [44], and instrumental support (i.e., explicit instructions) for letters and book reading [23]. However, gaps in adult literacy may have significant consequences for the quality of the home literacy environment. Prior work has found that children whose parents cannot read have lower language assessment scores and are less likely to complete primary education [66].

Educational technology in rural households

Educational technologies may be one method to help supplement gaps in formal literacy education in rural communities. Several meta-analyses of educational interventions in Sub-Saharan West African contexts found that investments in instructional technology—specifically, adaptive instructional technologies—had the largest effect sizes for improving student learning outcomes, compared with funding nutritional and health interventions, reducing class sizes, or providing financial incentives for attendance [15, 54]. Educational technologies have been deployed in many low-resource communities, using mobile devices in class [83], after school [35], across contexts [41, 64, 82], or using apps on e-readers [71] or tablets used in schools [62] or in both schools and home [81]. However, with few exceptions (e.g., [35, 64]), these systems have been designed for smart devices [33, 41, 60, 81, 83], despite significantly fewer families in rural communities owning smartphones than low-cost feature phones [48, 49]. Even in cases where families owned both smartphones and feature phones, as in Poon et al.'s work in Cameroon [64], they reported that parents preferred that children use feature phones.

Although many educational technologies are designed exclusively for in-school use (e.g., [35, 62, 83, 85]), others have been designed for learning across contexts—with the intent that children can continue learning at home or throughout their communities [41, 82]. However, despite the importance of the social ecology of the home environment for early literacy [44, 45], with few exceptions [65], the majority of these educational literacy technologies are not designed for parent engagement. To foster stimulating home literacy environments, researchers have built interventions to engage parents, such as sending SMS reminders to parents to teach letters or read stories (e.g., [19, 65, 70, 87]). However, this requires sufficient parental literacy to read the SMS and teach the lessons. Thus, even if educational mobile applications are designed for low-cost mobile devices, it is not clear whether and how such systems may effectively involve low-literate family members.

Voice-based technologies for low-literate users

Prior research on designing mobile interactions for low-literate users suggests that voice-based interactions are more effective than alternative modalities [55]. Existing approaches typically use either speech recognition, as in the SMART system [41], or IVR systems—as in the Baang and Polly systems [67, 86]. IVR systems have been widely studied in the CHI and ICTD communities for engaging low-literate users [46], as in work on agricultural voice forums [61], grievance redressal [52], community media [37, 56], and social networks, particularly for visually-impaired users [20, 68, 84]. However, prior IVR systems have largely been designed for adults seeking information [61] or entertainment [20, 68, 84], not for children's education.

Recent work has explored the use of IVR for assessing knowledge retention among adults, including the Sawaal system that assessed callers' knowledge of topics such as health, childcare, and local government regulations [69]. Although Sawaal does provide assessment questions, these questions are not part of a structured curriculum, nor are questions selected adaptively based on users' performance or progression through the curriculum. Another educational IVR, CapacityPlus, was deployed in Kenya to provide voice-based training on family planning to health care workers [32]. However, CapacityPlus was used by adult health care workers as part of their medical training for only a short duration (8-22 days). Thus, we do not know how children will use an educational IVR system at home over an extended period.

In sum, although educational technologies may help mitigate gaps in early literacy in low-resource contexts via out-of-

school learning on low-cost mobile devices, it is unclear whether and how such systems will be adopted by families, and how family members may support their children's use of a literacy educational technology, over time.

This leads us to ask the following research questions:

RQ1: What are motivations, methods, and barriers for rural families' adoption of a voice-based educational technology accessible via feature phones?

RQ2: What are motivations, methods, and barriers for rural families' support for children's use of a voice-based literacy technology?

RQ3: How does family support for a voice-based literacy technology change over time, when deployed with rural families?

METHODOLOGY

This study is part of an ongoing research program [31, 50, 51] to support literacy in cocoa farming communities, conducted by an interdisciplinary team of American and Ivorian linguists, economists, sociologists, and computer scientists, in partnership with the Ivorian Ministry of Education since 2016, and approved by our institutional review boards, the Ministry, and community leaders. Our work in this context has included French literacy assessments [31], qualitative needs-finding and co-design sessions with families [51], and pilot deployments of our literacy technology [50]. Below, we describe the design of an IVR literacy system, Allô Alphabet, we developed to foster phonological awareness; the study design and data sources; and a description of the study context.

IVR literacy system: Allô Alphabet

Based on guidelines identified in our co-design sessions with families in rural Côte d'Ivoire [51], we designed an evidence-based early French literacy curriculum and implemented it via an interactive voice response (IVR) system we developed: Allô Alphabet. Literacy is supported by many cognitive and linguistic skills including phonological awareness—the understanding that language consists of patterns of sounds and sound combinations. This is critical to emerging literacy, as it facilitates the ability to map sounds to the written representations of these sounds [10, 43]. The development of phonological awareness progresses from recognition that words are made of salient components, syllables, to recognizing that syllables are made up of smaller components, onsets and rimes, and then recognition of phonemes [26, 88]. We developed lessons designed to facilitate the natural development of phonological awareness and bridge these skills to emergent decoding. Because many children in Côte d'Ivoire speak French as a second language and may thus be less familiar with French words and phonotactics (i.e., the rules for how a language may combine sounds within words) [79], we use words and phonemes in early lessons that conform to the phonotactics of both French and the primary local language in the region, Attié [14, 22].

Our system provides instructions, questions, and feedback via voice messages recorded by an Ivorian researcher. Users provide answer input via touchtone. To initiate a session with our IVR system, users call the provided number, which immediately ends the call and redials the user's phone to help users avoid fees. At the start of each call, the system plays a welcome message, updates the user on their progress, and adaptively 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 pre-recorded audio message with the question and response options. After responding, students receive feedback on their responses. If incorrect, they receive the same question again, with a hint message explaining the concept or prompting the student to focus their attention on a particular part of the word or syllable. After one or two wrong attempts (depending on the question type), the answer is provided, with a brief explanation, and the next question is selected based on their mastery of the concept.

Prior work suggests that many families in rural communities in Côte d'Ivoire own feature phones [48, 49]. For this study, we provided a mobile device and SIM card to participating families for the duration of the study to enable a more consistent experience of using the system, based on prior evidence that differences in phone type impacted users' ability to access an IVR [32]. We chose the Itel IT5231 mobile phone, a model widely available in stores in our context. The device has a loudspeaker for playing voice messages hands-free, and 2G network accessibility, available in most of the region [49].

Context

The Adzopé region, located in southeastern Côte d'Ivoire, is primarily an agricultural economy based on cocoa and coffee, which has been the primary source of income of residents for decades [38]. The viability of these crops has also driven substantial migration to the Adzopé region from tribal groups in central and northern Côte d'Ivoire (e.g., Koulango, Baoulé, etc.), as well as from other countries in the Economic Community of West African States (ECOWAS) (e.g., Burkina Faso, Mali, etc.). Farmers mostly have small plots, managed by family members, and farming families often face economic hardship due to lean times between harvests, varying sizes of crop yields, and recent fluctuations in cocoa prices [16, 38]. There remain significant inequalities in the quality of life in villages across the Adzopé region, including poverty, lack of basic infrastructure, and agricultural, domestic, and commercial work involving members of families from rural communities dependent on farm production [38]. Although the official national language of Côte d'Ivoire is French, there are nearly 70 mother tongues, including Attié, widely spoken in the Adzopé region, as well as mother tongues for each tribal group [79].

Study Design

This paper presents data obtained during a larger randomized controlled trial (RCT) of the efficacy of Allô Alphabet in improving children's literacy, beyond the scope of this paper. Based on a power calculation for the RCT, we deployed Allô Alphabet with 16 randomly selected schools in 8 villages for 15 weeks. In each of the 16 schools, we recruited students from the CM1 class, with an average of 47 students per class who chose to participate in the study, for a total of 750 children. The average age was 11 years old (SD=1.5, min=8, max=17). 54% were boys and 44% girls (2% chose not to respond). At the start of the study, we provided a one-hour training for children

Data Source	Number of Participants
Enrolled in study	750
System users	236
Baseline survey	602
Endline survey	216
Interview participants	37

Table 1. Number of participants for each data source

and a caregiver, in which we explained the purpose of the study, distributed the phones and explained how to place calls and access SMS messages, and taught them to use the IVR.

Data Sources

Before distributing the phones, we surveyed the caregivers and participants to understand more about participants' home environment (e.g., family members' occupations, literacy, etc.). The survey and a baseline literacy assessment (not reported on here) were based on the Early Grade Reading Assessment [29]. After the study, we returned to the communities to collect the phones and administered an isomorphic endline literacy assessment to children and a reduced set of survey items to caregivers. We also obtained system log data (e.g., number and duration of calls, lesson performance, etc.). See Table 1 for more detail on the number of participants.

To investigate our research questions for this paper about why and how children and families adopted and engaged with an educational literacy technology over a sustained period of time, we conducted interviews and observations with families of 37 participants at their homes—15 families in the first month of the study and 25 in the final month of the study (3 participants were interviewed at both times). These interviews were conducted by an American HCI researcher and a linguistics graduate student from Côte d'Ivoire who spoke several mother tongues. These sessions were designed to observe how families used the system at home (though there may have been an effect of the researchers' presence) and probe deeper using semi-structured interviews with at least one caregiver. We conducted purposive sampling to meet with families representing a range of types of users from the 8 villages in the study. Half of the children were boys and half girls. The adults were 14 women and 23 men, with a variety of relationships to the children, including mothers (7), fathers (16), older siblings (5), and others. These adults held a variety of occupations, including farmers (10), homemakers (6), teachers (5), tailors (4), salespeople (6), and more. More detail is provided in Table 2. We took field notes and recorded and transcribed video and audio, for nearly 40 hours of data.

Inductive Thematic Coding

We adopted an inductive thematic analysis, modified from grounded theory methods for qualitative data analysis [13, 57, 80], similar to our prior work [50, 51]. Grounded theory is an iterative thematic analysis approach to emergent sense-making from data, with four levels of analysis: beginning with open coding of the raw data and finally organizing codes into a set of categories [80]. Three of the authors coded the transcripts, field notes, and observations and discussed our emerging themes, synthesizing the emerging codes as necessary to arrive at theoretical saturation [80]. Throughout

Relationship	Occupation	Participant ID
Father	Farmer, Driver, Salesperson, Misc.	(1,2,4,5,19,32, 35,37) (8) (9,26) (16,23,29,36)
Sister	Salesperson, Homemaker	(3,18) (27)
Mother	Homemaker, Farmer, Salesperson	(17,20,21,25) (7) (6,22)
Aunt	Homemaker, Unknown	(31) (10)
Uncle	Farmer	15
Tutor	Teacher, Farmer	(24) (34)
Grandfather	Teacher	28
Cousin	Teacher	33
Unknown	Unknown, Teacher	(11-13) (30)

Table 2. Interview participants' relationship to child; with interview participants' occupations grouped by parentheses

data collection, we conducted regular debrief sessions with our interpreters and other local collaborators to help resolve questions about concepts that arose during the interviews (i.e., "peer debriefers" [11]). We recorded these debrief sessions as voice memos and field notes and returned to these during coding to update codes and triangulate our data [13, 80].

FINDINGS

Family Literacy Educational Technology Adoption

Over 15 weeks of the study, a total of 236 participants called the IVR at least once, an average of 48 participants called per week (SD=28.7, Med=48.5), and an average of 15 participants called per day (SD=8.3, Med=13). The average call lasted an average of 5.7 minutes (SD=9.8, Med=3.1). The average child called in 24.3 times over the 15 weeks (SD=34.6, Med=12.5), but this average is skewed by 36 children who called once and never again. Across all calls, children attempted an average of 67 unique questions (SD=86.8, Med=34.0) and correctly answered an average of 35.7 questions on the first attempt (SD=51.4, Med=18.0). See Fig. 1 for call rates, and see *Limitations* section for factors impacting participation.

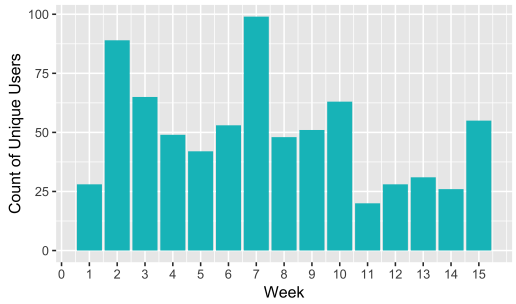

Figure 1. Unique users calling throughout the 15 weeks of the study

Caregivers want their children developing technology skills

In our interviews, we found that many caregivers believed that using technology to develop French literacy was important. In our prior needs-finding work, we found that parents valued their children learning French literacy as a form of social capital [51]. Here, we found that parents value technology as a medium to learn literacy so that children will also develop technology skills while learning to read. Caregivers described this motivation in terms of their aspirations for their family

to evolve and adapt with modernity, saying, *"Technology is moving forward. So we have to go beyond. We must not stay behind. We evolve."* (P18) Others framed this need to evolve in generational terms, describing their aspirations for children's skill development, saying, *"We have to prepare the children. For our youth in the future, maybe this will bear fruit."* (P24) Some caregivers' aspirations for children's technology fluency was influenced by increasingly ubiquitous mobile phones:

> *The situation has changed. I think kids now are addicted to technology, so it's a good idea to get them used to technology from the primary grades. I think our villages should not be on the sidelines.* (P34)

In fact, nearly all of the participants in this study had a family member who owned a mobile device living in their household. Of the 602 participants' caregivers who responded to our survey item on phone ownership, 600/602 owned at least one phone in their household (m=2.6 phones, SD=1.6, max=12). More broadly, the global trade association for mobile network operators, GSMA, reports that in the last 15 years, mobile ownership in Côte d'Ivoire has increased from 11% to 70% as a share of the population [49], mirroring broader trends across Africa [48]. Our results suggest that adults in these rural contexts are aware of these broader trends and aspire for their children to have the skills to use these devices. In addition to the aspirational value of learning to use technology, caregivers saw benefits in using technology to learn:

> *Mobile phones are a new method [for learning]. In the beginning it's difficult, but over time we will end up learning ourselves and then do well. If it can help the child to enjoy school again, it's good.* (P2)

Caregivers described how it was important for their children to learn with and *about* technology as a distinct learning goal. With increasing technological ubiquity, they wanted their children to be prepared with the skills needed in a changing world.

Caregivers are concerned about children using phones alone

While caregivers believed it was important for children to learn to use technology, they were concerned about their children using mobile devices for learning by themselves—they worried that children would use the phones for other purposes besides learning or the phones would be damaged, lost, or stolen. For most caregivers, the primary concern was that children would damage or lose the phones if they were left unsupervised with them. One mother told us how she considered having her daughter take the phone to her after-school tutoring lessons, but she was worried about the safety of the device:

> *I thought she might take it with her to her tutor, and they could work with it. Yet tutors have many students, up to 20 people or 30 people at a time. If it gets lost, what will I do? That's why I did not want her to take it—because they're going to steal it.* (P6)

Other caregivers were concerned that their children would be distracted by other functions on the phones, such as games, movies, or other apps. They told us how *"some kids, instead of studying with it, they take it to play"* (P9).

> *There is a worry about the device you gave her. Once she's learned the technology, is she going to slow down her education with Facebook or that nonsense?* (P18)

For this older sister, the very technology skills that others told us they wanted children to learn might enable her sibling to gain access to "nonsense" that could "slow down her education." For other caregivers, this burgeoning technological fluency might enable children to access things on adults' devices that they would rather the children not see. One father told us, *"I have a memory card like that in my phone. There are videos that my child should not see. If I give him my phone, he could access anything inside it."* (P19)

Caregivers control children's access to mobile devices

Because of these concerns about the phone's safety or children being distracted, we saw caregivers control their children's access to the mobile devices provided for the study:

> *I do not accept that he uses the phone alone. He always uses it with me, because if I let him use it alone, he will play video games and do things that I do not accept.* (P8)

This control over children's access was not limited to the conditions of children's use of the device, but also impacted where and how caregivers stored the devices when children were *not* using them. Caregivers described how they kept the phones with them until the child wanted to use it to study, saying, *"There are parents who are afraid for the phone's safety. This parent wanted to teach it to their children, and he told me that that his wife kept it until then."* (P31) However, if parents kept the phones with them for safekeeping, their children's access to the system would be limited when the parents traveled outside the village. Many caregivers described how they take the phone with them when they travel, because they were worried it would be stolen otherwise. One told us:

> When I travel, I keep it with me, because if I give it to my child, people will steal it. I left [my village] from the beginning of February until the end of March, and I kept the phone with me. I did not give it to my son. (P6)

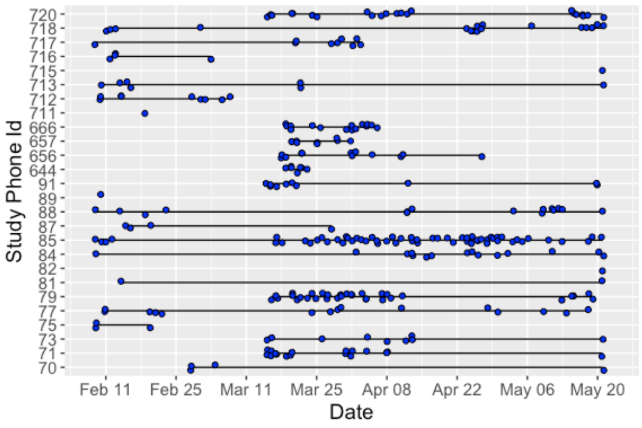

Figure 2. Patterns of IVR calls for one school, for 15 weeks. Each row is a user, and each dot represents a single call to the IVR for that user.

To understand these gaps in system usage, we showed participants a visualization of their individual calls throughout the

15-week study (Figure 2) and used this to prompt them about gaps in calling. Often, when we asked, the participants would point to a week-long gap between calls in the visualization and tell us they went to a farm or camp (*campement*) outside the village and brought the phone with them:

> *Parents are a little worried because sometimes they are in the field or sometimes they go to the camp. So if the phone stays with the kids, they might damage it.* (P30)

In sum, we found evidence suggesting caregivers view digital literacy for mobile devices as a learning goal for their children in addition to French literacy content. Despite this, caregivers are concerned about children independently using mobile devices, due to risks for the device's safety or children accessing other content on devices. To address these concerns, parents controlled children's access to mobile devices, often preventing children from using the phone to access the literacy lessons alone. Many parents kept the phones with them when they traveled, limiting children's system access to the system.

Family support for educational technology

We found a tension between the kind of support that caregivers wanted to provide for children's education and the support they were able to provide for children's use of the IVR during this study, given constraints on their availability and their own ability to use the system. To compensate for these constraints, we found that parents leveraged networks of support from others, including older siblings, aunts and uncles, and neighbors, which we found preliminary evidence of in a pilot study in one village [50]. We found further evidence for family support networks across all 8 villages in this study, and we extend our prior findings by identifying motivations and barriers for adult supporters to help children use education technology at home.

Parents support children's learning when available

First, parents described feeling responsible for supporting their children's education in various ways, from explicit instructional support to more implicit support, including: communicating with teachers to check on children's learning progress, providing resources like hiring private home tutors (as we saw in our co-design sessions [51]), or reminding children when it's time to study and ensuring they are completing their lessons at home. However, many parents in our context were not regularly available at home to provide explicit, hands-on support. The cocoa fields where many parents in the region work are often a long distance from the village, so adults either return home late in the day, or are sometimes gone for several days at a time, living at the field with other cocoa farmers. Nevertheless, many parents still supported children's learning:

> *Every night, I give him exercises. It's a bit hard for them, because I'm not here sometimes. I'm at the camp. But when I come home, I give them exercises.* (P5)

For some parents, the educational support they provided their children was predicated on their ability to be present with the child to give them exercises, prompt them to work on their lessons, or provide explicit support for learning:

> *Here in an agricultural region, most of the time everybody leaves the village for their business, so I'm here today but tomorrow I'll be gone. The days we are at home, we add more to our children's learning.* (P10)

As the communities we worked in were primarily cocoa farming communities, agricultural work was widespread. Of the 226 adults who responded to a survey item on their current work, the plurality (73 (32%)) reported working in agriculture, with the majority of those in cocoa farming, and a small number farming rubber or other vegetables, while other adults worked selling goods in the market (38 (17%)), and others self-identified as a homemaker (67 (30%)). Even caregivers who were not farmers also traveled both within and outside their village for their business. One mother who sold goods in the local market told us, *"I'm never in one place. If he wants to study, he can take his notebook to read by himself because I'm so busy."* (P22) For this mother, the choice of whether to learn with a notebook was left up to the child, unlike the control we heard parents describe for mobile device usage, perhaps because of the relative costs of notebooks and mobile phones.

Figure 3. Father and son using IVR in the father's shop

Other family members help children use education technology

We found that parents recruit other family members to help their children use the IVR to develop literacy, to compensate for constraints from parents' availability, educational experience, and technological fluency. Because parents were not comfortable with children using mobile devices alone and they traveled often for work, they asked others to help:

> *We go to the bush for field work, so the children are here with the big brother who is in CM2, who is there to help. He helps them study before giving the exercises. After that the mobile phone is always kept by my wife. We too, when we are there, we call the child, and he reads a little with us. It is we who help him to do everything.* (P2)

This parent described how the older brother (only one grade above CM1) and the parents collectively supported children's learning. When parents could not provide explicit, instrumental support, they asked older children or other family members to help, before returning the phone back to the parent for safekeeping. In addition, we found that parents recruited

other family helpers to support children's system usage when they felt they lacked sufficient educational background to provide explicit, instrumental help with the lesson content:

> *Those who can help their children are those who have gone to school, those who can read. They could explain to the child how to do the exercises. Those who can not read can not help their children.* (P11)

The issue may not have been with caregivers' explicit content knowledge, but instead with their self-efficacy, or belief in their ability to help. In fact, because the literacy content was provided via IVR, no prior French literacy was necessary to begin the lessons. Interestingly, while that participant believed that people who could not read could not help their children with Allô Alphabet, we found many others provide implicit support for children's learning: communicating dispositions towards learning, providing effective learning environments, or providing the metacognitive, regulatory support of reminding or motivating children to use Allô Alphabet. We saw other parents without formal education describe instances of just these types of implicit support, including supporting by recruiting other family members. We also found that despite widespread phone ownership, parents who felt they lacked sufficient ability to use the IVR and SMS system recruited other family members to help with Allô Alphabet:

> *I gave the phone to my child and then I sat and I watched him use it. At first, my son did not know how to use it, he did not understand what was being said... I do not know how to manipulate it. So I called my daughter, who showed my son, 'Here's what you have to do.'* (P8)

In spite of the ubiquity of mobile device ownership in these communities (99% of participants), caregivers may not have had experience with IVR systems, or may not typically use their SMS functionality if they are not sufficiently literate in French themselves. While some caregivers described other family members helping their children with exercises and lessons prior to the intervention, in other cases, we heard from caregivers who explicitly told others to help only when the IVR system was introduced, because they did not know how to use an IVR, despite using other mobile functions:

> *Before the phones arrived, I did not take care of [my sisters' learning]. Because I too had other concerns. I was going to school too. [Our parents] do not know how to manipulate the system. That's why I've been asked to direct them.* (P31)

This case was indicative of other family members who were recruited to help because the caregivers did not know how to use SMS or IVR system, despite owning a phone. Support from other adults was widespread. Of the 216 children who responded to the survey item at the end of the study on whether they had support with the IVR from someone else at any point in the study, 155 of the 216 (72%) respondents reported that they had support, while only 61 (28%) responded that they did not have support. Of the 155 children who had help, 110 (71%) reported that their primary helper was someone who was not their parents, of which 48/110 (31%) reported having a sibling as the primary supporter.

Gaps in availability of family supporters

Although many families did recruit other adults to help supervise or provide explicit support in using the IVR to learn, in many cases these supporters were not always available themselves, with many family members going to the camp to farm:

> *Other than me, I do not know who will stay next to her so that she can use it with them. If it's not me, there's no one here. All my brothers are not here. We do not see our neighbor. Sometimes he goes to the camp. If he does not go to the camp and he's here, he's busy.* (P20)

These supporters' availability may be impacted by seasonality of the cocoa harvest and by school holidays and closures. Older siblings who were still in school may have left the village to work on the farms when *their* schools were closed:

> *Right now maybe they have their brothers, who go to school, who can help them. Parents can call them, 'Come, you're going to help the child.' But once the holidays have arrived, those brothers have gone to the camp. The child is no longer near the brother.* (P11)

Children's independent educational technology use

Although we found that having a family supporter was widespread, the survey did not shed light on the nature of that support, nor how it changed over the 15 weeks of the study. Using interviews at both the beginning and end of the study, we found that adult supporters transitioned from explicit support to a more supervisory role, despite their original concerns for children learning alone with phones.

Adults fade explicit support for children's independent IVR use

In the beginning of the study, we heard that adults, whether parents, siblings, or other adult caregivers, would provide explicit, directed guidance for the literacy lessons, similar to our findings in a preliminary, short-term study [50]. This explicit support was common across families, including support for the digital skills of dialing the IVR number, accepting the auto-callback from the IVR, and responding to multiple choice questions with touchtone presses. Over the 15 weeks of this study, however, we found evidence that parents and siblings transitioned from providing explicit instructions to more implicit monitoring or supervising of children's learning.

We found evidence suggesting that caregivers changed the nature of their support when they perceived that their child no longer needed explicit help calling the IVR number or answering the questions after being given some initial guidance.

> *At first I used it with him. I put on the loudspeaker, so the phone speaks and we all hear, and then I say, 'You have to answer now.' At first, he did not know how to handle it alone; he had never manipulated a phone. They gave me instructions on how to use it. When I taught him that, we did it together two or three times and then he typed the number himself, he listened, and he worked with it. That's when I left him alone.* (P3)

Another parent described how, after their older daughter had helped their son use the IVR and SMS components of Allô Alphabet, they felt their son no longer needed explicit support:

Since we showed him, he does not need help anymore. Now, he himself knows how to write and send SMS. So since then, he uses it alone, but I am here and I monitor and observe him. (P8)

Interestingly, for this participant, and for others, even when the child "uses it alone", the parents were nearby to observe and monitor the child. This also suggests that, for some parents, learning independently may mean that although children may not need explicit instructions, parents may still want an adult to monitor them while they use it.

Parents wanted children to become autonomous learners

This transition in the nature of adult support for children's learning with Allô Alphabet was also driven by beliefs from some parents that it was important for children to develop the ability to learn independently—specifically, to choose when they want learn and to regulate their ability to ask for help if needed. One father (who was previously worried about children using phones "to play") told us, *"If the child is aware, if he likes to study, the phone is good. It will improve his student abilities."* (P9) Caregivers also believed children should be responsible for other parts of life.

I'm not going to force you to wash, be clean, stuff like that. If you have exercises, I can help you, but it depends first of all on the child: if he wants to study. (P17)

Further, some caregivers believed that family members' explicit learning support should only be provided when children recognize that they need help and ask parents' for it.

I prefer that if she does not understand something, she will tell me, 'Dad, here I was asked the question but I do not understand anything.' Then I can explain and then it will continue. It is not good for the father to come every time to support the child. (P13)

At one extreme end of this belief in self-regulated learning and child-driven help-seeking, some parents forbade others from helping children, saying *"I forbade his sister to help him, because we want to see his brain work on its own. If he has trouble, we can help him afterwards."* (P3) This suggests that some parents believed it was important for children to develop the ability to become autonomous learners.

Children wanted to use the system independently

This shift from adults' explicit support to a more implicit role was also driven by children's desire to learn more independently. We found that some children began to take the initiative in choosing when to use the IVR, despite reluctance to learn with notebooks prior to the study: *"If you do not tell her to go get the notebook, she won't, but with the phone, she herself decides to use it."* (P7) While some of this may be attributed to the novelty effect of a mobile device, we primarily found evidence of this in interviews conducted at the end of the 15 week study. *"[My daughter] tells me when she will study with it. She told me, 'Mom, I want to study with it,' so I give it to her."* (P37) It is possible that there may be other motivating effects of learning with technology, including motivational aspects of an adaptive learning system, the "charisma effect" of technology [2], or social cachet of children using mobile phones.

DISCUSSION

This study is part of an iterative co-design project with family members and community stakeholders in rural communities in Côte d'Ivoire to develop an educational literacy technology. After co-designing and developing a voice-based literacy curriculum for low-cost mobile devices [50, 51], we deployed Allô Alphabet with families in 8 rural communities in Côte d'Ivoire for 15 weeks. In this paper, we identify how and why children and their families used Allô Alphabet, using interviews with 37 families. In this section, we highlight key themes that emerged from this work, and discuss implications for the design, deployment, and adoption of educational technologies for families in low-resource, rural environments.

Designing for digital literacy skill acquisition

As mobile devices have become increasingly ubiquitous in communities around the world [48, 49], educational technologies are increasingly being developed and deployed on these devices, including smartphones [41] and messaging services for smartphones and feature phones [64]. Our findings suggest that caregivers want their children to develop digital literacy as a distinct skill, but this skill development may be both a motivator and inhibitor for the adoption and use of educational technology. Our data suggests that caregivers drive technology adoption (cf. as "enablers" [36]) via their belief that digital literacy is a critical component of children's education, and part of caregivers' aspirations for their families' future (cf. [42]).

However, we found that caregivers were concerned that children who were *too* technologically fluent might be able to access other features of the phones that would distract them or that might be embarrassing for the parents. In our prior co-design sessions with families, caregivers expressed similar concerns about children's use of mobile devices [51]. We see evidence for this here after our system was developed and deployed. These concerns extend prior research on caregivers' concerns about children's online behavior—primarily conducted with families in the Global North [25, 27]. We uncover caregivers' concerns for children's mobile phone usage in rural communities in Côte d'Ivoire, and identify how these concerns impact adoption of an educational technology. This suggests further work to design for parental control or involvement in children's educational technology use in rural communities (cf. [27]).

For designers of educational technology considering a deployment in low-resource contexts, it is critical to consider the nature of the digital literacy skills needed to use the system, and how widespread such skills may be. In our work, we see that despite ubiquitous feature phone ownership, children and their family supporters nevertheless had difficulty using the interactive voice response system. This suggests that educational technologies may be a resource to help families in low-resource contexts fulfill aspirations for children's technological fluency, but those children—and their caregivers—may need support in achieving this. Although the interactions on the device (i.e., dialing numbers and answering calls) may have been familiar, the interaction modality of the IVR system (i.e., listening to recorded messages and pressing buttons to select responses) may have been novel.

Nevertheless, many family members were still able to provide explicit support for the feature phones, in ways that may not have been possible with less ubiquitous technologies (e.g., smartphones [41] or tablets [81], etc). Thus, designers of educational technology intended for low-resource contexts should consider which features—or interaction paradigms—of their systems may be widespread in their context and which may be less common (e.g., voice-based recorded messages).

To design to support digital literacy, educational technology designers may draw from the field of learning analytics, which has developed robust methods for identifying and clustering skills (or, "knowledge components") [12, 39]. However, designers of educational systems often model the content knowledge—here, French literacy or phonology skills. Future work may thus consider designing computational models of students' digital literacy skill acquisition using system data or assessments and suggest support from family members or other supporters at the right time, such as when students encounter content requiring new interaction modalities (e.g., opening an SMS message). For designers of interactive voice systems (e.g., [52, 56, 61, 67–69]), our findings suggest that, if such systems are to be designed for children, they should be designed to explicitly scaffold technological fluency for IVR.

Designing for collective support for education technology

Prior work has identified various roles that parents play in their children's education (e.g., teacher, collaborator, resource broker, monitor, etc.) [5, 18]. We advance that work by demonstrating how parents in resource-constrained environments distribute these roles across a collective of multiple adult supporters. In some cases, we found evidence that parents play a teacher role for the French literacy content or the mobile device use itself, depending on their literacy and technological fluency, but in many other cases, we found that parents designated older siblings, neighbors, or other adults in the household to take on this teacher role, as well as the roles of collaborator and monitor. In our prior work in this context [50, 51], we found preliminary evidence for these collective, distributed support networks in children's learning. In this study, after our IVR was deployed at scale, we identified motivations for family supporters to help with educational technology at home—to compensate for constraints from parents' availability due to farm travel, parents' educational background or self-efficacy, or gaps in parents' technological fluency.

Prior research on technology intermediaries has identified how people without sufficient technical abilities may recruit intermediaries to support information-seeking with technology [74]. Here, we advance these findings by showing how caregivers recruit intermediaries for children's educational technology use and delegate instructional support responsibilities to them. Unlike Sambasivan et al. [74], the intermediaries in our context are supporting educational interactions, not information-seeking, and thus need to provide pedagogically appropriate support, without simply giving children the answer (cf. [40]). This suggests that designers of educational technologies for low-resource contexts should explore how to scaffold pedagogically effective support from multiple adult supporters acting in intermediary roles. For example, supporters may want to access their children's progress (as they did by talking to teachers, prior to this study [51]) or obtain suggestions for methods to support their child. As these support networks are often distributed, multiple individuals may take the responsibility to help the child in different ways. Thus, designers of educational technologies could develop personalized recommendations for the nature of such support, based on adults' literacy levels, availability, or the types of support they provide.

Finally, these support networks for children's education are part of a larger tradition of family support in Côte d'Ivoire (e.g., [4, 9, 21, 38, 76]). In agricultural communities in Côte d'Ivoire, family members provide support for critical services that they (or the communities more broadly) may lack the resources to provide, including support for family health [9] and financial resources [4, 21, 38]. In addition, as the cost for hiring laborers during the harvest season may be prohibitively expensive, family members who are old enough are recruited to help support the family's agricultural efforts, often carrying food, water, or supplies to the parents working in the fields [76]. However, these multiple support networks may mean that demands on family members' time are widespread, limiting their ability to support children's learning. We even found that many families were unable to find family members in their own household who could consistently provide support for Allô Alphabet. Some of these families thus asked neighbors for support, if they were available, or some families paid for tutors to help (as we saw in this context prior to the start of this study [51]). This suggests opportunities to design methods for coordinating adult support for children's educational technology usage. This may entail multiple families joining together to have a single family member provide educational technology support for children from each family together, as some families are already doing in an *ad hoc* manner [50], and which we saw further evidence of in this study. This may also entail providing scaffolding for independent use of educational technology if supporters are not consistently available.

Designing for negotiated autonomy in learning

Early in this study, caregivers shared how they wanted to provide hands-on, explicit support for literacy (cf. [45, 78]) and wanted to control children's use of mobile devices. After 15 weeks of deploying Allô Alphabet, however, we found evidence that the nature of the support that caregivers and other supporters provided transitioned to a more hands-off, supervisory role. In part, this transition occurred due to constraints in family members' availability, but more often, family members perceived that children were developing the ability to use Allô Alphabet independently, and children were increasingly interested in using it independently. To understand this transition, we draw on the concept of negotiated autonomy [7, 73] in parent-child relationships, as well as prior research in children's self-regulated learning [75]. This research suggests that children may set goals for their own learning and development, shaped by intrinsic and extrinsic motivational factors, and may work towards those goals in ways that may be supported by "autonomy support" behaviors from parents and other meaningful adults in their lives (e.g., [17, 24, 75]). However, the extent to which children are motivated to set learning goals varies widely, as does the extent to which parents and

other adults foster or inhibit children's burgeoning autonomy through controlling behaviors or autonomy support behaviors (e.g., [7,17,73]). Some have proposed the concept of parenting styles to characterize parents' interactions with their children, categorizing these into "authoritarian", "authoritative", and "permissive" [3], and others have studied these parenting styles in West African contexts [34,53,59], suggesting that parenting style may impact the parents' position towards children's learning autonomy. In our study, we found evidence that children desire autonomy and control over their learning with technology and that this desire is supported in part by some caregivers' desire for their children to become autonomous learners.

This suggests opportunities to design to support this negotiated autonomy in learning with technology. First, we found that children began to initiate the learning sessions on their own, after learning how to start lessons with the IVR. This suggests that educational technologies in low-resource contexts may be designed to foster learners' intrinsic motivations for learning and provide opportunities for them to initiate learning at times and contexts that are appropriate for them. However, while some designers of mobile learning technologies posit that children may learn with smartphones across village contexts [41], our findings suggest a more negotiated, circumscribed independence, where children may use the device independently, but this may only occur within the confines of the household, under supervision of the adults who control access to the device itself. This also suggests opportunities to support children in identifying and setting their own learning goals on a regular basis, providing them feedback to help them monitor their progress in achieving those goals [75]. While this practice has been adopted in other contexts, there remain open design questions as to how best to design this metacognitive support for low-literate children learning with low-cost feature phones or voice-based systems. There also remain rich design opportunities for how to most effectively involve low-literate adult supporters in supporting children's self-regulated learning in rural contexts.

The transition from explicit (e.g., instructional) to implicit (e.g., supervisory) support from caregivers suggests design opportunities to help adults fade this support over time—and for re-introducing this support when needed. For instance, designers might create prompts for adult supporters to re-engage more explicitly if it appears that the child needs help on particular concepts. Although we found that caregivers expected their children to ask for help when needed, prior research on children's help-seeking has shown that there are often metacognitive or social barriers for explicitly seeking help, such as knowing that they need help, knowing who to ask or how to ask, in addition to the social "face-threat" of asking for help [1,58]. Thus, future educational technologies for families might provide alerts to adult supporters when it appears that children are "wheel-spinning" [6] without making progress, or provide support akin to the "invisible hand-raising" suggested by Holstein et al. [28], perhaps delivered via SMS messages or automated voice calls, depending on adult literacy levels.

Limitations and future work

Although we distributed phones and SIM cards to 750 participants, only 236 users ever called to access the IVR. This was due in part to a new law in Côte d'Ivoire requiring all SIM cards to be registered to individuals, using government-issued photo IDs. A local telecom company registered participants' SIM cards during the training sessions for all 750 families. Unfortunately, we encountered significant problems registering SIM cards, including participants not having caregivers with a government-issued photo ID. Thus, over 400 participants were not able to have their SIM cards successfully registered and could not access the IVR, impacting overall participation rates and suggesting additional lessons for educational technology deployments in rural contexts. For our next study, we have obtained permission from the Ivorian Ministry of Telecommunications (ARTCI) to register all SIM cards with the national organization of parent-school partnerships (COGES) to circumvent this problem. This study was also limited to 15 weeks, which may not reveal nuances in family behavior over a longer period of time; we plan to conduct future studies for longer. Although we used survey items about whether children had support, we did not ask about the nature of that support; future surveys will use information learned in interviews to ask about specific types of adult support, as well as families' prior experience with voice systems (e.g., IVR). Finally, a 6 week national teacher strike occurred during the study, during which all schools were closed. Future work will explore educational technology usage during sustained school closures, including the possibility for children to use educational technology to supplement formal schooling during closures.

CONCLUSION

Educational technologies have been proposed as a solution for supporting education in low-resource, rural contexts where formal schooling is insufficient in fostering widespread literacy. Despite this potential, challenges remain to the effective design and adoption of educational technologies in low-resource contexts. We conduct semi-structured interviews with 37 families to investigate motivations, methods, and barriers for rural families' adoption, use, and support for a literacy technology accessible via feature phones, and how that family engagement changes over an extended deployment. We find that families view digital literacy as a distinct learning goal, they leverage networks of supporters to help children learn with technology, and over time, they transition support from more explicit to more implicit support for children's independent learning. This work suggests further opportunities for design, deployment, and adoption of appropriate educational technologies for families in rural contexts, particularly for literacy technologies to scaffold low-literate family support.

ACKNOWLEDGMENTS

This research was supported by the Jacobs Foundation Fellowship, Grant No. 2015117013, and the Institute of Education Sciences, U.S. Department of Education, Grant No. R305B150008. We thank our participants, the village chiefs, school leaders, and COGES directors for their time and help, and we are indebted to all of our collaborators at the Jacobs Foundation TRECC Program and Eneza Education.

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