# Understanding and Scaffolding Family Literacy with Voice-Based Technology in Rural Côte d'Ivoire

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## Abstract

Despite an overall rise in global literacy rates, these gains have not been evenly distributed. Rural communities in low-resource contexts—as in cocoa-growing regions of Côte d'Ivoire—face complex challenges in fostering children's early literacy. Although families and the home environment are critical precursors for early literacy, in multilingual contexts with low adult literacy in the language of schooling, parents and other caregivers may face challenges in supporting children's literacy. Given the ubiquity of low-cost mobile devices in Sub-Saharan Africa, educational technologies may be able to complement the support that children are receiving for their literacy development at home. However, it is not clear how such technologies may be designed in ways that most effectively fit into families' existing literacy practices, nor how children and their families will use such technologies at home in multilingual agricultural contexts.

In this dissertation, I present insights from a multi-year, iterative design-based research program in which we designed and deployed a voice-based technology to support family literacy in rural communities in Côte d'Ivoire. I present insights from our qualitative research with Ivorian families, as well as findings from 3 deployments of our system, Allô Alphabet, with over 1,000 families in 8 villages over several years. Using a mixed-methods approach involving semi-structured interviews as well as quantitative analyses of surveys, assessments, and system log data, I investigate motivating and inhibiting factors and patterns of use for children and families' adoption of Allô Alphabet.

This thesis makes contributions at the intersection of the learning sciences, human-computer interaction (HCI), and information-communication technology for development (ICTD) with implications for family learning with technology beyond the Ivorian context. I discuss design implications for designing technologies to support family literacy, particularly voice-based systems in multilingual contexts, and conclude with a discussion of the role of power and politics in educational language technology research and design.

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# Chapter 1

# Introduction

Access to literacy is critical for unlocking opportunities for children's future educational attainment and economic outcomes [101], as well as providing access to what Amartya Sen has called "the opportunity for people to live lives they have reason to value" [211]. 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 [197]. In agricultural communities, farm labor is associated with lower children's literacy and increased risk of school dropout from primary school [190]. Educational technologies may help supplement gaps in schooling in low-resource, agricultural contexts [49, 156], but such technologies are typically used primarily at school [240, 182]. In contexts where children may miss days of school due farming [190], it is critical to understand the role that technology may play in supplementing home literacy learning.

Decades of research in early literacy learning has demonstrated the crucial role that parents and other adult caregivers in the home environment play in supporting children's literacy [133, 212]. This support may take the form of explicit instruction of letters [78] or joint reading activities [136]. In addition, parents and other adults in the home environment may also model productive learning attitudes or dispositions [46], provide a supportive socio-emotional environment or "secure base" in which children may develop literacy [183], and provide a stimulating language environment for their children [90].

However, in contexts where adult literacy is low, and particularly in multilingual contexts where children are learning to read and write in a language their parents may not be literate in, children may not have access to a sufficiently stimulating home literacy environment. Moreover, the bulk of the research described above was conducted in predominantly Western, educated, industrialized, rich, and democratic (WEIRD) contexts, with predominantly literate parents. Although substantial prior work has studied family learning processes in non-Western contexts with multilingual families of mixed literacies [198, 199, 200, 154], this work has not formed the basis for the currently widespread approaches to designing child-focused or parent-supporting educational technologies used at home (e.g., [256, 195, 219, 174, 189]), suggesting that it is critical to first understand family literacy beliefs and practices in low-literate, multilingual contexts, before designing technology to scaffold those existing practices. Côte d'Ivoire is one such context, where adult literacy rates (53% of adult men and 33% of adult women) lag far behind the regional and global average [141]. In addition, children enter the Ivorian school system with highly varying levels of early literacy, speaking a wide variety of mother tongues in addition to (and often instead of) French [215, 103], which presents significant challenges to effective in-school education. However, the high degree of mobile phone penetration in Côte

d'Ivoire, much like many developing contexts [140] suggests opportunities for technologies to supplement in-school literacy instruction, with additional support for literacy learning in the home environment.

In contexts where participation in agricultural labor may constrain children's educational attainment and family literacy [190], previous interventions have proposed using educational technologies, such as laptops [240, 42], tablets [229], and smartphones [127] to supplement in-school education. However, such approaches may be indicative of what some have referred to as an *invention* framing to technology in international development [179] (or what others have referred to as "techno-solutionism" [165, 161, 208], where researchers and technologists develop and introduce new technologies into resource-constrained contexts to address complex social issues, which may not lead to sustainable impact without existing infrastructures or assets to support their adoption and use. In this work, I engaged in an iterative design-based research process with family members and community stakeholders in rural communities in Côte d'Ivoire to develop an educational literacy technology that would be appropriate for their context and conducted a series of studies to understand how that technology was integrated into ongoing family literacy practices.

Prior work has designed mobile literacy systems for developing contexts [189, 127, 121], but with few exceptions [256, 195], these systems focus on the child alone, and do not engage with the parents or other adult supporters in the home environment. The educational interventions that have designed scaffolds for parental support have primarily targeted literate parents in Western, educated, industrialized, rich, and democratic (WEIRD) contexts [256, 195]. As many have argued, educational interventions designed and evaluated with one culture and community in mind are not likely to generalize to other cultures and communities [79]. Additionally, while significant prior work has focused on how to design technologies for low-literate users in developing contexts, using interactive voice response (IVR) [160, 150, 177, 192, 191], these systems have typically not been designed for children to use for learning, and have not addressed the unique socio-cognitive design challenges of designing for adult support for literacy development.

In sum, while substantial prior work has demonstrated the importance of the role of the family in the social ecology of early childhood literacy acquisition, many literacy technologies are often designed exclusively for the child, and not for fostering and leveraging existing family literacy practices. Meanwhile, the work that *has* designed scaffolds for parents has been designed for literate parents in American contexts. There is thus a need to understand how early literacy technologies can be designed and used in ways that fit into existing family literacy practices in the target context.

To address this gap, I investigate the following high-level research questions (discussed in more detail in each study chapter):

**Study 1, RQ1:** What are parents' beliefs, values, and goals for their children's literacy in rural communities in Côte d'Ivoire – and what do they want from technology that might support literacy?

**Study 2, RQ2:** How do rural Ivorian children and their parents and other adult caregivers use a voice-based literacy technology in rural communities?

**Study 3, RQ3:** How do rural Ivorian families engage with and support children's use of a voice-based literacy technology – and how does this change over time?

**Study 4, RQ4:** Which child- and household-level factors impact the adoption and use of a voice-based literacy technology?

To investigate these research questions, I conducted a design-based research program [17, 75] across four iterative studies. Our first study (Chapter 3) used interviews, storyboards, and

prototyping methods with families in several rural communities in Côte d'Ivoire to understand families' beliefs and practices for French literacy learning and to understand what families would want from (or be concerned about) for a technology to support chilren's literacy development. Then, in the second study (Chapter 4), we designed and deployed an early version of our voice- and SMS-based early literacy instructional system using low-cost mobile phones with 40 families in one village in Côte d'Ivoire, to understand how children would use such a literacy system and how their families would engage in the learning process. Then, in the third study (Chapter 5), we deployed Allô Alphabet in 8 villages for several months, using qualitative interviews and observations to understand the nature of family engagement with children's literacy learning with Allô Alphabet over time, supplemented with system log data and a survey. Finally, the fourth study (Chapter 6) was intended to be a randomized controlled trial, in the same 8 villages. However, at the time of writing, schools are closed due to COVID-19, and thus the endline assessment has been delayed until schools re-open in fall 2020. In this final study, I use survey data of children and caregivers to understand how various child- and household- factors impact families' adoption and children's use of Allô Alphabet. Then, in Chapter 7, I discuss the contributions of this research and implications for future design and research.

This thesis contributes to learning science research by providing insights into the collective nature of family support for children's literacy development with educational technology—including (1) that family supporters provide explicit instruction in literacy concepts and methods for technology usage as well as socio-emotional and motivational support for learning, all of which is positively associated with multiple measures of children's use of our education technology; (2) that these collective support networks comprised of multiple family members are leveraged to compensate for gaps in parents' literacy, technological fluency, or availability; and (3) that learning support roles are distributed across these supporters, with different supporters playing different roles at different times, sometimes intentionally coordinated and at other times contested among the supporters.

In addition, this thesis contributes to human-computer interaction and information- communication technology for development (i.e., HCI4D) research, design, and policy by providing insights into the ways in which children's adoption and use of voice-based mobile educational technology at home is mediated by these family support networks, including—(1) challenges that children face in using voice-based systems for learning phonology in multilingual home contexts and strategies that family supporters leverage to overcome those challenges; (2) the role that family mobility (within and across villages and the cocoa farms) plays in impacting children's access to mobile devices for learning and an adult supporter who mediates the use of that device; and (3) how family supporters fade out their explicit support and supervision of children's use of an educational technology over time out of necessity, when children may still lack the self-regulation and meta-cognitive capacity to learn independently with technology. I conclude the thesis with a set of design implications including designing for family literacy support, designing to support children's learning autonomy, and implications for considering the role of power and politics in education technology.

# Chapter 2

# Background

In this chapter, I discuss some of the relevant background literature, including prior work on the social ecology of literacy learning in the home environment; educational technologies in low-resource contexts; designing to support family engagement in learning; designing technologies for low-literate users; and design-based research more generally.

## 2.1 The social ecology of the home literacy environment

Many education scholars give social mediation a leading role in literacy acquisition [133, 89]. Literacy researchers have long advocated for learning in the home environment as an essential complement to the literacy development that continues at school [66], with others arguing that designers of educational technology should design for the complex "social ecology" of children's lives [184, 225, 226]. The home environment thus represents a crucial element in a learning ecosystem that bridges home, school, and informal out-of-school learning spaces. For the purposes of this dissertation, we define literacy as the ability to map written characters (i.e., graphemes) to sound units (i.e., phonemes, syllables, and words) in a target language (here, French), and combine the smaller units (i.e., phonemes, then syllables) to form larger, more complex units (i.e., syllables, then words). See Chapter 7 for a longer discussion on the culturally situated nature of literacy and the political dimension of literacy education, particularly in former colonial contexts, as in Côte d'Ivoire.

Children's exposure to language at home is supported by parents' explicit literacy-building activities such as story reading [54], letter naming [78], joint reading [136], and others (see [133] for a review). Parents and caregivers may also provide informal experiences for children to learn letter-sound mappings: singing songs with rhyming syllables, manipulating magnetic letters, or reading environmental print [77]. In addition to the benefits of the *instrumental* support of book reading and letter naming [136, 78], parents provide *metacognitive* support for maintaining children's attention and scaffolding self-regulation [133], as well as *motivational* and *dispositional* support by communicating to children that literacy-building behaviors have value [183, 46]. For instance, parental support for maintaining children's attention, contingent responses to children's behaviors, and scaffolding self-regulation are all beneficial for children's emerging literacy development [133]. Such parental verbal scaffolding, assessed during everyday routines, has been shown to indirectly influence both decoding and comprehension, through its direct influence on children's language abilities at 3 and 4 years of age [66]. Further, children's motivation to engage in literacy-building interactions (learning letter-sound combinations; playing rhyming games, storybook reading) is fostered by parents and peers communicating that

these behaviors have value [183].

However, parents with low or nonexistent literacy, or parents who are not literate in the target language their child is learning, may be less likely to provide much of the support described above, or may provide it in different ways. Prior work has found that children whose parents cannot read have lower language assessment scores and are less likely to complete primary education [190]. 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 [141]. These gaps in adult literacy may have significant impacts on home literacy practices. The explicit instructional support described above (e.g., book reading, letter naming, describing objects in their everyday environment) may be particularly difficult for low-literate parents [76, 135, 239, 97]. Although other home literacy practices such as motivational and dispositional supports may be feasible, it is not clear how these behaviors manifest in rural Ivorian contexts, and thus how technology may be leveraged to support existing family home literacy practices.

Parents' literacy support is only one part of what some have referred to as the "ecocultural" context for learning, in which children's development is a co-constructive process, involving individual factors (e.g., self-efficacy, goals, beliefs), interpersonal factors (e.g., relational support from peers, parents, and other adults), and socio-cultural factors of the larger home environment and community context (e.g., local political and economic conditions, cultural norms) [225]. In her work with cross-cultural learning, Barbara Rogoff has identified "guided participation" as a process by which children are socialized into cultural knowledge and practices via continued participation, observation, and, sometimes, explicit instruction and modeling by adults and near-peers [199]. Rogoff describes how adults provide a structure for interactions and experiences with others in the family and community who guide children in developing skills and knowledge in an apprenticeship model [198, 199]. In addition, others, such as Maynard and Gregory, have identified how older siblings may play a mentorship role for younger children [88, 154]. Maynard examined the role of older siblings in teaching younger children to "become competent members of their culture by guiding them in cultural activities" in their work in Mayan communities [154], while Gregory identified how close-age siblings provided literacy support for oral story comprehension in multilingual families in London [88]. In some contexts, this may take the form of older siblings "trying on" the instructional behaviors of their teacher at home, with varying levels of success [178]. Particularly in socio-cultural contexts where older siblings may be more likely to act as caregivers [154], younger children may be more likely to imitate their older siblings, and older siblings more likely to provide socio-emotional learning support beyond simply providing instructions to their younger siblings [200, 178]. Introducing educational technologies into families' home environment, however, may alter these family literacy dynamics, as Uchidiuno et al. saw in their work on tablets used to support learning at home in Tanzanian villages, where they found that siblings were less likely to proactively offer younger children learning support unless explicitly asked [229]. It is thus not clear whether or how the nature of family literacy support in low-literate, multilingual contexts as in rural Côte d'Ivoire may be impacted by the introduction of educational technology designed to foster literacy.

## 2.2 Educational technology in low-resource contexts

Despite growth in global literacy rates, children's literacy in Sub-Saharan African contexts has lagged behind, particularly in agricultural communities with low adult literacy, as in rural Côte d'Ivoire [190]. Educational technologies may be one method to help supplement gaps in formal education in rural communities and low-resource contexts more broadly. 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 [49, 156]. Some of these initiatives have focused on the role of community centers as informal learning spaces, as in David Nemer's work on the role of community care in fostering learning in telecentres in Brazilian favelas [167], or Ellen Zegura and my prior work on informal computer science education in the iLab Liberia tech hub in Monrovia, Liberia [258, 259, 144], or more recently, Azra Ismail and others' work on MakerGhat in rural India[1]. Other informal community learning initiatives have been designed for video-based instruction to support maternal mental health in rural India, as in Kumar et al. [128].

In formal schooling, educational technologies have been deployed in many low-resource communities, including laptop computers such as the oft-critiqued One Laptop Per Child project [240, 8], deployed in rural communities around the world (largely without piloting it in those contexts [9]), as well as less well-known projects, such as the use of desktop computers in rural Peru [223] and others (see Unwin et al., 2017 for a review of ICT in low-resource contexts [231]). Some of these interventions have been designed for apps on e-readers [196] or tablets used in schools [182, 93] or for tablets used in both schools and home, as in Uchidiuno et al. [229, 228]. Given the ubiquity of mobile devices in low-resource contexts [140, 141], prior work has developed literacy interventions designed for mobile devices (see [241] for a review). For instance, Ojanen et al. developed a smartphone app to help children recognize phonemes [174], and Kumar et al., developed voice-controlled literacy apps for rural India, [127], while another quizzed students in Zambia on the written form of various phonemes in ciNyanja [106]. However, with few exceptions (e.g., [186, 109]), these systems have been designed for smart technologies such as tablets [229, 228] and smartphones [233, 127, 174, 106] (with some developing and piloting virtual reality (VR) interventions [237]), despite significantly fewer families in rural communities owning smartphones or tablets than low-cost feature phones [141, 140]. Some prior research has developed interventions for feature phones, as in Poon et al.'s work on SMS test prep interventions in Cameroon [186, 187]. In the private sector, mobile educational technologies are on the rise across Africa[2]. Particularly in the wake of COVID-19, adoption of ed tech in Africa has increased[3], although much of that increase has been for a small number of platforms (at least one of which is for educational TV), one of which is Eneza Education, an ed tech company with whom we have partnered for this research, which Kizilcec et al. have evaluated for their SMS test prep interventions in Kenya [122].

In addition to educational technologies developed for smartphones and feature phone applications that use SMS, some companies are beginning to design ed tech using *interactive voice response* (IVR) technology. IVR systems play pre-recorded audio messages sent over the cell provider network, and users can press touchtone buttons on the phone to select different options (see [191] for one non-educational exemplar). IVR systems have been developed for a wide variety of purposes (see Section 2.3 for more detail), including for education, where they have primarily been used to access information about schooling. Recently, several companies have developed IVR systems for instruction, including Gyan Vani [4], which uses IVR to connect students to a teacher, based on information on their school and grade level, as well as other IVR systems to provide instruction for adults learning English as a second language, such as

[1]https://makerghat.org/
[2]https://edtechhub.org/database/
[3]https://edtechhub.org/2020/05/19/why-the-covid-crisis-is-not-edtechs-moment-in-africa/
[4]https://graymatterscap.com/toll-free-numbers-sms-missed-call-schools/

English Seekho [175] and Jobseeker IVR [227]. However, these efforts, as well as others for using IVR to teach healthcare workers [105] have targeted adult learners learning a second language, not children using the IVR to learn to read. Thus, while voice-based systems such as IVR may be appropriate for low-literate users, it is not clear how they may be most effectively designed to support children's literacy learning, given differences in children's motivations and need for additional support.

Although many educational technologies are designed exclusively for in-school use, as in One Laptop Per Child [240, 8], and many others (e.g., [182, 233, 109]), others have been designed for learning across contexts—with the intent that children can continue learning at home or throughout their communities, as in Kam and Kumar's work on mobile learning on smartphones in rural India [127, 109], and Valderrama Bahamóndez et al.'s work in rural Panama [232] (see Nye, 2013 for a discussion of cross-context ICT for education in low-resource contexts [171]). However, despite the importance of the social ecology of the home environment for early literacy [136, 133], with few exceptions, such as the MobiLiteracy project, [189], these educational literacy technologies have not been designed to explicitly scaffold families' home literacy practices, as discussed in Section 2.1. Thus, it is not clear whether or how families might be involved in supporting children's literacy once educational technologies are introduced at home. Will they replace families practices? Will children use them independently? Will family members get involved, or as Uchidiuno et al. found [229], will they only help if explicitly asked?

## 2.3 Designing for low-literate users

Prior research on designing technologies for low-literate users suggests that voice-based interactions are more effective than alternative modalities [160, 4, 176]. Existing approaches have proposed using either speech recognition, as in the SMART system [127], or interactive voice response (IVR) systems (i.e., systems with pre-recorded audio messages that play various menu options after the user presses a button or records a message)—as in the Baang and Polly systems [191, 247]. African researchers have argued that existing natural language processing research (which provides the foundation for automatic speech recognition) often lacks the resources (i.e., a data corpus in a useful format) to "train" the language models for speech recognition [57], although research in this area is progressing [73, 173, 162], with recent industry efforts for developing ASR for under-resourced languages[5].

IVR systems have been widely studied in the CHI and ICTD communities for engaging low-literate users [137], as in work on agricultural voice forums [177], grievance redressal [150], community media [164, 116], and social networks, particularly for visually-impaired users [192, 234, 70]. However, prior IVR systems have largely been designed for adults seeking information [177] or entertainment [192, 234, 70], and not for children's education. Some 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 [193]. Although Sawaal does provide assessment questions, these questions are not part of a structured curriculum, nor are questions selected 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 [105]. However, CapacityPlus was used by adult health care workers as part of their medical training for only a short duration (8-22 days).

[5]https://foundation.mozilla.org/en/blog/mozilla-welcomes-two-new-fellows-voice-technology/

Further, the majority of IVR systems primarily target a single end-user, rather than designing for parents or other family members involved in the social ecology of the home learning environment. Other work on designing technologies for multiple low-literate users, however, *has* explored the role of technology *intermediaries* who assist the primary user in operating information technology [204, 113, 114, 172]. For instance, Sambasivan et al. identified design considerations for low-literate users who rely on intermediaries to help read and understand information on their mobile devices [204]. They uncovered several forms of intermediation—for inputting information into a device (e.g., in searching online), for interpreting device output, and for surrogate usage (i.e., intermediating both information input and interpretation of output). Marisol Wong-Villacres et al. have extended Sambasivan's framing to identify the ways that parent-school liaisons assemble *information patchworks* to engage parents in children's schooling. While these forms of intermediation are important, this prior work on tech intermediaries focuses largely on the intermediary providing information to the user for information-seeking purposes, and thus does not shed light on the role of intermediaries in a learning context, where the active role of the learner is critical for learning [125]. In addition, when designing for low-literate family support for literacy with a voice-based technology or on mobile devices, it may not be clear which user (e.g., parent or child) is the intermediary and which is the primary user, or how to effectively leverage support from other elements of the socio-cognitive ecology for learning (e.g., teachers, other adults in the community, etc).

Further, for many low-literate adults in bilingual contexts, the primary challenge may be that they are not literate in the language used in school. Particularly in former colonial contexts where the official language of instruction is the language of the colonizers - as in French in Côte d'Ivoire - the national language policy may serve to further disenfranchise adults who speak local languages and not the official language [6, 32, 45, 181]. These differences between parents' language and the official language of schooling may result in parents feeling that they lack what Bourdieu refers to as "cultural capital" [34] to engage with teachers and schools [249]. Wong-Villacres et al. have conducted extensive research in identifying the role that parent-school liaisons play in bridging these gaps, for bilingual Spanish-speaking families in an urban context in the U.S. [252, 253], finding that these liaisons leverage technology tools as well as linguistic and cultural resources to manage the "seams" between Latino immigrants and school culture. See Chapter 7 for a longer discussion of the legacy of French colonial education, and the relationship between multilingual families and public schools in Côte d'Ivoire.

## 2.4 Designing to support family engagement in learning

Prior work in the CHI and Interaction Design for Children (IDC) communities has highlighted the importance of incorporating families into the design process of learning technologies, from Yip et al. who identified how parent-child relationships impact the co-design process [255], to Wong-Villacres et al. and Khanipour et al., who identified design guidelines for supporting parents' engagement with schools in low socio-economic communities [249, 119]. Others, such as Barron et al., have identified a set of roles that parents play as "learning partners" in the development of their children's *digital* literacy [21]. This work has been extended to understand the roles parents of various socio-economic strata play in accessing information about out-of-school learning experiences for their children [67]. Such work suggests that even when parents may not have the domain experience to provide explicit help for their children, parents may still play the role of resource broker, mentor, or even collaborator or co-learner, among others [21, 67]. Relatedly, Banerjee et al. identified the roles English language learning parents play in

engaging with their children in learning programming, suggesting alternative ways of supporting children's learning even in domains where parents may have no content knowledge [15]. To do this, they suggest using text-free (for programming, block-based) interfaces, in addition to fostering collaborative, reciprocal learning in joint learning environments available for families to learn to program together at home [15].

To support home literacy, some researchers have designed technological interventions to engage parents (see Spier et al. for a review of non-technological interventions [219]), such as sending reminder messages to teach letters or read stories [256, 68, 195, 189]. Some mobile literacy systems, such as MobiLiteracy [189], Ready4K [256, 68], and Sesame Street's literacy app [195], *have* incorporated approaches for parental support such as sending reminder messages for parents to teach letters, read stories, or teach literacy lessons [189]. Some of these studies did demonstrate an increase in parents' (self-reported) frequency of joint reading [256] and letter-naming [195] activities. However, others described an inverse relationship between the time parents spent teaching the system's lessons and they time they would have spent engaging in traditional literacy-building activities, such as reading to their children [189]. The few literacy systems that do involve parents in the intervention often require that the parents themselves are sufficiently literate, either to read the reminder messages sent via SMS [256, 195] or to teach the lessons provided [189]. This work draws on behavioral economics literature on "nudging", or providing messages or reminders to prompt or stimulate some action to lead to better outcomes for the recipient of these nudges (see [60], for a review of nudges in educational interventions).

In addition, prior work suggests that parents' engagement with their children's education is strongly associated with the families' socio-economic status (SES) [76] and the parents' literacy [239]. Parents' SES, their literacy, and their own education level are associated with parents' self-efficacy, or their belief in their ability to meaningfully contribute to their children's education, which may directly impact their motivation and likelihood to participate in that education [76, 135]. This is not only due to parents' individual beliefs, but parents' self-efficacy and willingness to engage may also be shaped by parents' relationship with the school, particularly if they are part of marginalized communities, or language-minority communities [249, 250, 252]. As a result, it is not clear how educational technologies that seek to meaningfully engage parents and family members in the social ecology of the home learning environment may foster such engagement in ways that are aligned with—and complementary to— existing family literacy educational practices in a given context, particularly for bilingual or multilingual families in low-literate, low-resource contexts.

In sum, while prior work has developed mobile literacy systems to support children's literacy development in low-resource contexts, and developed voice-based systems for low-literate adults, it is not clear how children will use an educational voice-based technology. Secondly, while prior work on technology intermediaries highlights the role of literate users' supporting low-literate users in accessing information via digital interfaces, it remains unclear exactly how other members of the family may act as an intermediary for supporting children's learning with a voice-based educational literacy technology at home.

## 2.5 Design-Based Research

In this thesis, I use a design-based research (DBR) approach, drawing from Barab [17] and Easterday et al. [75]. The DBR approach is an iterative, mixed-methods research approach, which uses collaborative design with multiple stakeholders to iteratively refine our understanding of a particular phenomenon-in-context, while generating situated knowledge. This situated

knowledge is then used to design and evaluate a learning environment intended to positively impact the stakeholders and contribute to the development and refinement of theories-in-context, where learning is understood to be embedded in the socio-cultural, political, and historical context in which learning occurs. Proponents of the DBR method argue—based on others [98, 134]—that cognition is situated in particular contexts and distributed across the actors and artifacts in that context [17]. Thus, the nature of the cognition observed in learning settings is always already intertwined with and contingent on the webs of socio-cognitive relationships with other learners, teachers, parents, and others in the community [178, 203, 17].

To develop this"situated knowledge", then, DBR approaches take an iterative, recursive process of meaning-making, beginning with framing the design space in collaboration with stakeholders, understanding the context, developing a novel system or intervention based on theory and understanding of the context, and evaluating the system deployed in context [75]. In this way, knowledge generated from each of these stages can both contribute to future stages, as well as allowing the researcher to deepen their understanding at each stage. The following chapters of this dissertation describe 4 studies, as part of a design-based research framework. For each study, I will discuss system design decisions made on the basis of findings from the preceding study. The aim of this dissertation is to develop a contextually appropriate design intervention, and iteratively understand and evaluate its adoption and use, aiming to ultimately contribute to refining and developing a robust understanding of technology-enabled family literacy learning informed by and interwoven within the context of rural communities in Côte d'Ivoire.

# Chapter 3

# Understanding Families' Literacy Practices and Desires for Support (Study 1)

## 3.1 Overview

As described in Chapter 2, there remain significant open questions about how to design literacy technologies that engage family members in helping foster children's literacy, particularly for multilingual or low-literate families in developing contexts. In this chapter, we report on findings from nearly 60 hours of semi-structured interviews, storyboard "speed-dating" [61], and prototype testing conducted with educational stakeholders over several months. This chapter is adapted from a paper published in CHI, 2019 [148].

As the first phase of a design-based research approach, we sought to address the following research questions in Study 1:

**RQ1.1**: What are parents' beliefs, values, and goals for their children's literacy in rural communities in Côte d'Ivoire?

**RQ1.2**: What are parents' desires and concerns for children learning with mobile technology in rural communities in Côte d'Ivoire?

To help us understand the particular beliefs, preferences, and desiderata for literacy systems intended to scaffold adult support for children's literacy, we conducted a qualitative study of educational stakeholders (parents, children, teachers), in two distinct regions of rural Côte d'Ivoire.

## 3.2 Context

As described in the last two chapters, literacy and education are cultural practices that reflect the cultural-historical specificity of the context. Thus, I will first describe here some features of that context which may influence the design of systems intended to foster parental engagement in children's literacy.

### 3.2.1 Regional overview

This study was conducted in three villages in two rural cocoa producing regions in south-east and south-west Côte d'Ivoire—two villages in the Adzopé region and one village in the Soubré

region, respectively. The two regions are composed of dense and humid vegetation, with plateaus near Soubré and low plains in Adzopé. As of the most recent census in 2015, the village in Soubré had 2,822 inhabitants, Adzopé village 1 had 6,619 inhabitants, and the largest, Adzopé village 2, had just over 24,610 inhabitants [63, 62]. While French is the official language and the one in which business is conducted, there are over 60 languages actively spoken in Côte d'Ivoire. Only 6.9 million of the 23.7 million Ivorians speak French, and of those, 6.8 million speak it as their second language [215]. In our research sites, the primary languages spoken by the populations is Attié in Adzopé and Bété in Soubré (although we saw later in Studies 3 and 4 that there were over 20 unique languages spoken in these communities).

### 3.2.2 Infrastructure and Economy

The rural economy of the south-east and south-west regions is largely dominated by cocoa production. In the Adzopé region, 57% of 122 children surveyed in an earlier phase of this research reported working on a cocoa plantation, while in the Soubré region, 41% of 106 children surveyed reported working on a cocoa plantation. Additionally, in Soubré, many people cultivate rubber in addition to cocoa farming. This additional source of income enables households in this village to have a median income per capita of around 100,000 FCFA / month ($171.82), as of 2013, the last year on record [118]. 80% of the population of both regions are connected to the national electricity grid and have cellular coverage from the three major Ivorian mobile operators - Orange (42%), MTN (34%) and Moov (24%), with technological equipment for 3G+ internet access [64]. In addition, despite its small size, the village we worked with in Soubré has a radio tower and broadcasting station, as well as an agro-industrial latex processing factory.

There are also significant regional differences in socioeconomic status at a household level, as indicated by results from a household inventory index given as part of an earlier phase of this research, asking about the presence of 15 household amenities (e.g., television, running water, phones, etc). Households in Soubré reported having significantly ($t(330)=4.977$, $p<.001$) more household items (M=6.52, SD=2.42) than households in Adzopé (M=5.15, SD=2.45), though populations surveyed in both regions commonly use mobile phones, with 88% (Adzopé) and 89% (Soubré) of 334 children surveyed in the two regions reported having a phone at home. Although 81% of children surveyed in Soubré lived in homes with running water, 36% with toilet facilities, and 97% with electricity at home, none of the children surveyed in the Adzopé region lived in homes with running water, only 20% reported toilet facilities, and only 83% reported having electricity at home.

### 3.2.3 Educational Context

In Adzopé, village 1 has five schools, including four primary schools that teach in French and one school that provides bilingual education for early grade levels for learning in both the local language (Attié) and French. Though French is the official language of instruction, as in many Francophone West African countries [45, 32], the Ivorian government recently instituted a program (PEI) to incorporate instruction in the mother tongue at early grade levels and transition instruction to the French language over time [38]. However, that policy has not had full implementation in all schools in Côte d'Ivoire. The second village in Adzopé has five primary schools, none of which teach in the local language of the community. The schools in these two villages primarily use teachers hired from the local community, paid for by members of the community via a community fund. In Soubré, the village we worked in also has three primary schools, one of which is dedicated to learning in the local Bété language in addition to

French. All of the schools in each of the three villages in this study are public schools, under the authority of the national government. In general, education is free for all children aged 6 to 15 throughout the country. However, parents are expected to pay for various other educational expenses for uniforms, school supplies, contributions for the examinations, and payments for the local community-school association, *COGES* (Management Committee of Public School Establishments).

In an earlier phase of this research, 830 students aged 6 to 14 years (M = 9.56, SD = 2.13) were assessed for their literacy levels, finding that across each of the 3 sites discussed in this chapter, children were below grade-level expectations for reading fluency. That study used the Early Grade Reading Assessment (EGRA) tool, with performance standards based on other French-speaking African countries (e.g., Senegal). The minimum level expected for students to be on-track for literacy is between 45 and 60 words per minute for a Grade 3 student in the French version of EGRA [188, 7]. However, we found that across our 3 sites, children at grade 5 are reading significantly below this level, with students in Adzopé village 1 reading an average of 11.7 words per minute (SD=13.58 wpm), students in Adzopé village 2 reading an average of 14.7 wpm (SD=15.66), and students in the Soubré village reading an average of 26.11 wpm (SD=18.88). Thus, students in the Soubré village are closest to reading fluency, though they still remain significantly below the average literacy level in Sub-Saharan West Africa.

## 3.3 Data Collection

To understand the design considerations for parental support for mobile literacy systems, we conducted semi-structured interviews, storyboard speed-dating, and prototype tests with children, parents, and teachers in the villages. We worked closely with the directors of schools, the village chiefs, and the head of the local parent-teacher association (COGES), to ensure that our study would be as minimally disruptive as possible, and would adhere to local customs and norms for meeting with children and families. Throughout April and May 2018, we spent several weeks in these communities, collecting over 60 hours of audio and video data, not all of which is reported on in this chapter.

Participants were recruited through a combination of identification by the head of the COGES, as well as a convenience sampling of walking through the village, and knocking on the doors of the families who were home, both during weekdays and weekends, to ensure that parents would be available. Our team was comprised of HCI researchers, Ivorian linguists, as well as an interpreter from a nearby village in each region, who translated the local language (e.g., Attié in Adzopé, and Bété in Soubré) for parents who had difficulty with French, and who ensured that we adhered to local norms and customs for meeting with parents at home. For the study reported here, we conducted interviews with 17 parents (7 in Adzopé and 10 in Soubré), from 13 families. We interviewed 10 fathers and 7 mothers, with ages ranging from 25 to 53 (M = 35.33, SD = 9.66). Parents' occupations were mostly farmers of cocoa or rubber farms, with one reporting working in information technology (*informatique*). Nearly all parents were bilingual, with Attié or Bété being their primary language. Most spoke enough French to conduct the interview partly in French, though significant portions needed to be translated to their mother tongue to explain certain concepts. Two parents spoke only Attié, and two spoke only Bété during the interview, with one speaking only Baoulé.

The whole session, including the semi-structured interviews and storyboards, ranged in duration from 45-90 minutes. We attempted to interview parents individually whenever possible, though for some families the husbands requested that we interview them and their wives to-

gether. This reflected a more broadly patriarchal gender dynamic at work in the families. The interviews were conducted around a set of themes relating to parents' daily life with their children, parents' and children's use of mobile phones, and parents' beliefs about and involvement in their children's education, among others. After the semi-structured interview, we showed parents a set of storyboards to exemplify possible interactions and explore divergent design concepts, asking parents about their preferences for the design concepts. We follow [61] in using a *speed-dating* approach to presenting structured comparisons of design concepts, to allow the juxtaposition of alternative designs to surface preferences and design considerations that might be otherwise missed [61]. An example of one of the storyboard sessions can be seen in Figure 3-1.

Figure 3-1: Storyboard "speed-dating" with Ivorian parents

## 3.4 Data Analysis

To understand the most salient themes from our data, we adopt an inductive thematic analysis approach for qualitative data analysis from Braun and Clarke [36]. 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" [221], 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 sensemaking from data, my collaborators and I went through the coding process and discussed our emerging themes, synthesizing the emerging codes as necessary to arrive at what is referred to as theoretical saturation, or the point at which our data is fully described by our codes [221].

Throughout the data collection process, we conducted regular debrief sessions with our interpreters and others from the Soubré and Adzopé regions to help resolve questions about

concepts that arose during the interviews and validate our emerging themes—what Brown et al. (2002) describe as"peer debriefers" [40]. We recorded these discussions about emerging themes and our introspective reflections as voice memos, and returned to them later during the initial open coding process to triangulate with our other data sources, as part of a "constant comparison" approach to the data analysis [43, 221].

## 3.5 Findings

In our interviews with parents in two rural regions of Côte d'Ivoire, several major themes emerged, clustered around 1) parents' perceptions of local economic conditions and the quality of schools; 2) parents' beliefs, attitudes, and values about French literacy; 3) the ways in which parents and family members are involved in children's education; 4) parents' attitudes towards their family's mobile phone usage; and 5) parents' desired contexts for children's learning.

### 3.5.1 Economic Conditions and School Quality

Across our data, concerns emerged about the local economic conditions and the quality of the schools in the region. Given how often during our time in the villages people discussed these issues with us—both during the interviews and in casual conversations—I will discuss this theme first, as it provides a critical context for understanding the rest of the findings.

In both regions, we heard parents describing how the local economy impacted their children's education. In Adzopé, parents described the limited job opportunities in the region, and how even after completing school, they were concerned their children would not be able to find a job in the village. In Soubré, we heard from many parents who described how economic conditions had recently worsened in their region. Specifically, one participant described it in an interview as such:

> *"Cocoa is old. The earth is not good. It does not produce much. There is not a lot of money. Before, when there was still a lot of money, when the land was still good, there were bananas, there was everything."* [SP10]

Other data we observed corroborates this account of worsening economic conditions in the Soubré region. On our first day in the village, we met several men on the road to the local school who began the conversation by telling us (unprompted) how the price of cocoa had recently dropped significantly. According to Reuters, in April, 2017, roughly a year prior to this data collection, the Ivorian government had reduced the guaranteed price for cocoa farmers by 36%, to 700 CFA francs ($1.14 USD) per kilogram of cocoa [53]. Though not all adults in the village farmed cocoa, in nearly every home we visited in Soubré, parents described finding it hard to afford enough food for their family, perhaps due to the reduced price of cocoa, with many telling us about recent increases in local rubber production as a result [SP10].

Across both regions, parents described concerns about the quality of the local schools, though parents in the two regions differed in their level of trust in the teachers and their engagement with the schools. For parents in Soubré, they voiced concerns about the quality of the local education, with one mother describing not being "satisfied with the way [the teachers] teach, because they do not teach as they should" [SP9]. Parents in Soubré also described concerns about teachers being chronically absent from schools and advancing students' grade levels before they obtain the necessary skills. In light of this, parents described paying for tutors (*maître du maison*) to supplement the schools' education, as one father describes:

*"The education system in Côte d'Ivoire has changed so much that the children must have tutors, because without the tutors, I am sure that the child cannot make it out of the education system."* [SP4]

This parent was one of many we encountered who paid for a tutor to teach their children at home, though parents varied in their reasons for paying for these tutors, which we discuss in more detail in subsequent sections.

In Adzopé, while some parents did describe their concerns about the schools' quality, these concerns were largely focused on the physical school infrastructure (e.g., "the roofs that are there... start to leak" [AP7]). In fact, in the Adzopé region, significantly more parents described their engagement with the school. Parents described the roles they took on at school (e.g., "student parent", "treasurer" [AP6]), saying that they regularly called teachers on the phone. In Soubré, by contrast, while one teacher we spoke to described having parents' phone numbers that they called if their children were absent, none of the parents in Soubré mentioned that they called the teachers themselves. In Adzopé, parents told us of their desire to "reinforce" at home what the schools are teaching their children. Parents in Adzopé also described paying for tutors, as in Soubré, but instead of hiring them to fill in gaps in what children were learning in school, parents told us how they hired the tutors "to reinforce what the teacher gave [the children]" [AP3]. This suggests a trust in the school curriculum that did not seem to be present in Soubré. In spite of this trust, however, children's literacy rates were lower in the two villages in Adzopé region than in Soubré, perhaps related to the differences in SES between the two villages.

### 3.5.2 Attitudes towards French Literacy

Another set of themes from our interviews revolved around parents' beliefs and attitudes towards French literacy. This is particularly salient for designers of educational literacy technologies in multilingual contexts, as in Côte d'Ivoire, where there are likely to be differences between the official language of instruction and families' home language [32, 6, 94]. If parents don't believe the language being taught is important for their community, they may be less likely to adopt the system or support their children's use of it at home. Parents from both Soubré and Adzopé told us how they felt it was important for their children to learn French in order to communicate with others, find jobs, and travel around Côte d'Ivoire beyond their village. One parent described the importance of learning French as providing access to economic benefits:

*"Because it's an intermediary language that can allow them to have access to a lot of things. When you speak french, you have access to a lot of things. You can have a job. You can travel."* [SP3]

For this parent, French is an "intermediary" language to communicate with people from other villages or regions, who might speak a different mother tongue (e.g., Attié, instead of Bété), and which could provide his children with access to jobs and "many things". Multiple parents referenced this idea that learning French would allow their children to travel and access opportunities:

*"The French are the ones who colonized us. If you leave here and you do not understand French, you cannot evolve, you cannot travel. It is necessary to learn French. It is not so bad to learn French. You must understand French."* [AP6]

Other parents across regions also echoed this tension around learning the language of the colonizers, with others saying reluctantly "we are colonized by the French, so one must necessarily

learn French" [SP1], and it is "an obligation" [SP1] for children to learn. This aligns with the current state of Francophone West African linguistic policy, with educational, economic, and political affairs conducted in French, limiting access to such activities to French-speakers [45, 32], despite a minority of the population speaking French [215].

Beyond their specific attitudes about French, parents described at length the benefits of literacy for their children in "advancing the family" [SP1]. One parent described children who can read as a "relay" (*relais*) for the family:

> *"The child is the relay of the parents. So, when the child knows how to read... you can trust the child with tasks later because little by little they will grow up. These are the children who will take our places tomorrow. The children who know how to read are relays."* [SP4]

Other parents echoed how literate children could be given responsibilities such as helping around the house by reading and writing notes for parents, or buying lists of items at the store. As one mother put it:

> *"I can send my child out into the world without worrying, knowing that my child knows how to write... If I see that they are planning to go out alone to the shop nearby, I can write a little something, 'buy me a biscuit'."* [SP5]

Participants across both regions were explicit about the types of jobs their children could get if they were literate in French, suggesting that they could become "a great administrator" [SP3] or "manager" [SP9], "a teacher" [AP6], "a building engineer" [SP4], or even "CEO... or a minister" [SP1]. However, many of these suggestions were highly gendered, with such career options often mentioned exclusively for the male children, with parents often saying that their daughters should "master a woman's tasks... clean the house, sort the rice... wash the plates" [SP9].

Parents' attitudes and values towards French literacy in these rural Ivorian communities reflects the socio-political landscape of Côte d'Ivoire, where French is the official language of schooling and business, despite being spoken by a minority of Ivorians. Thus, families' home language and literacy practices in highly multilingual contexts, such as rural Côte d'Ivoire, may not be in the official national language (i.e., French), suggesting a tension for a literacy technology designed to support literacy instruction in the state language at home.

### 3.5.3 Family Literacy Practices

In addition to parents' beliefs and attitudes about literacy, another set of themes emerged about how parents supported their children's literacy development. Some described communicating their beliefs and values about education to their children through advice, stories, and encouragement (similar to [183, 133]), while some described supporting their children's literacy through instrumental support (e.g., teaching letters, as in [212]) and providing learning resources (as in [67, 21]).

> *"The responsibility is on both of us, it's me and my husband who are responsible for the child. One way or another, everyone in the house brings their grain of salt in reinforcing the education of the child."* [SP9]

This idea that many people in the household come together to each contribute "their grain of salt" to support children's education was echoed throughout many of our interviews. This suggests that an educational technology intended to be used at home, might be able to leverage the ecologies of support for children's learning we find here (and described elsewhere by [225, 184]). In the rest of this section, we describe some of the different practices family members use to offer this support.

### Communicating educational values

One of the ways parents in our data supported their children's literacy was by communicating their values and beliefs about the importance of literacy and ways of learning (as in [46]). Some did this through stories or advice, as in one parent who described how they tell their children that "it is reading that makes man evolve" [AP6], while others told us how they told their children about the economic consequences of *not* learning to read: "If you do not study, then you do not know and if, for example, I die and leave you all alone, what are you going to eat?" [AP7]. Many parents told us how they gave their children advice and encouragement to continue learning, as this parent describes how she tells her children to "pay attention to everything [they learn] at school because that is what will allow them to move ahead" [AP3].

Other parents supported their children by communicating specific dispositions for learning ([46]), with one parent describing how she would tell her children that mistakes were part of learning:

> *"In learning, one is allowed to make mistakes. So I can tell the child 'It's alright you did not get it today. What is important is that you don't give up.' "* [SP9]

This echoes what prior research has suggested about the benefits of productive failure in learning [111], and suggests that an adult-scaffolding literacy system (such as [256]) that provides support for parents or other adults to communicate or model productive learning dispositions for their children would be aligned with existing practices in these communities. In Chapter 6, we describe how we used this guideline to inform the system we developed for adult supporters.

### Instrumental support

In addition to communicating their values about the importance of literacy and modeling effective learning dispositions, some parents across both regions told us about how they provide what is often called "instrumental support" through explicit instructions in writing or letter reading [133, 212].

Though it was not common among our participants, some parents described teaching their children how to read or write specific letters on a chalkboard at home:

> *"Every night, I tell him, you must take your slate and go study. We have a board there. Children stand in front of it and they study. Whoever doesn't know 'A', I write it on the board, I show them look: this is how you write 'A'."* [AP7]

This parent is teaching their child the names and written form of letters, in similar ways as we observed teachers teaching in class. However, as with much of our data, the parents' motivation for engaging in their children's education was shaped by their relationship with the local school system. This was summed up by one parent, who described the role of parents as reinforcing what the teachers were teaching:

*"When he arrives home, his father must tell him again what the teacher said at school, he must say: this is what the teacher said, this is what it means... We must explain this to our children. We parents, we have our own homework too. We must help the teachers with the development of our students. If we don't, what is done in class, is not enough."* [AP6]

This idea of parents "having their homework" echoes the parent who told us how each person brings "their grain of salt" to reinforce the education of the child. For this parent, that entails helping teachers with the development of the child at home, but we can see echoes of the parent in Soubré [SP4] who told us that without having additional help, their child would never make it out of the school system.

**Providing resources for learning**

Parents also supported their children's education in other ways, such as by paying for private tutors to teach their children at home, as in 8 of the 11 families we interviewed with children of eligible ages for tutoring. This is one way parents in these communities play the role of a "learning resource broker" for their children's education [21, 67]. Some parents we spoke with told us that, while they *wanted* to help their children learn, they were often too busy or tired to help their children at night (e.g., "Because some parents are busy doing activities, they do not have the time" [AP1]). As one parent said: "sometimes when we come back from the fields, we are tired, that's why we hire the tutors" [AP6]. However, parents expressed concern about the price of these tutors and described pooling funds with other families to pay for a tutor for several children, with some tutors teaching groups of up to 30 students across grade levels, limiting the individual attention they could provide, much like in schools. Parents describe investing in tutors - whether to fill in gaps in schools' education or to reinforce it - as well as investing in physical resources, such as the slates or chalkboards that we saw in the majority of homes we visited in both regions (Figure **??**), writing materials for their children, or even "storm lamps" that children could use to finish their homework at night. However, as described above, despite these efforts, children in these two regions remained well below developmental thresholds for literacy [103], suggesting opportunities to supplement home literacy learning.

### 3.5.4 Attitudes towards Family Mobile Usage

The fourth cluster of themes that surfaced in the interviews with parents centered around parents' attitudes and desires about their family's use of mobile phones. Parents in every family we visited had more than one mobile phone in their family, with every parent in the families interviewed having at least one "basic" phone (e.g., feature phone), four parents having at least one touchphone, and one family with up to six phones. Parents told us that they used their phones on a daily basis, with one parent telling us how she calls people "three or four times a day" [AP7]. In several interviews, parents took phone calls during the interview, some answering multiple calls during a single one-hour interview.

Parents described using their phones to call family members and friends, to support their work on the job (e.g., to calculate "how much I need to produce such a number of chickens" [SP3]), and to connect to global information networks (e.g., "We are trying to surf the net, to use Facebook to see what is happening elsewhere." [AP6]). This desire to connect to a larger information community mirrors what we heard from parents about the benefits of French literacy for their children. Many parents we spoke with were interested in the potential for their children to use their mobile phones not just to learn literacy, but also to learn how to

Figure 3-2: Child demonstrating his family's chalkboard

use the phone itself. For some parents, the phone presented an opportunity for their child to learn about technology, saying: "...because it's to know, to know what is inside it. In this too, she can know, know the things that are in there, especially the internet" [AP4]. One parent describes how in addition to learning to read in French, "they master more things that are in the phone itself... that in any case can make them intelligent." [AP3]. Other parents describe how they are willing to "give the mobile to our children so that they advance in their education, we are ready for that. We want the advancement of our children's education." [AP7]. For these parents, access to mobile devices and the Internet may provide their children access to global information resources and social networks.

Some parents told us at length about how their children already used their phones quite often, but some parents described wanting their children to wait for permission to use the phone. Some families described how only the older children were allowed to use their parents' phone, typically to talk to family members, who had moved away to Abidjan for work [SP3, SP4]. For other families, parents described a more permissive attitude towards their younger children using the phone to "play music" [AP4], "play games" [AP3], or "become familiar with what's on the phone" [AP3]. One mother described how her children pick up and use her phone if she leaves it lying around the house:

> *"It's been a year since she got the phone and everyone uses the phone. When she puts down the phone, the kids use it, and start playing the games with her phone."* [AP3]

This attitude was not present in all parents we interviewed, however. Some parents described how they would allow their children to use the phone, but only after giving permission:

*"The child also has his rights and his duties, so if he wants to play, he asks me permission to play for at least a few minutes, I can do that."* [AP6]

This desire to give permission to the children before they could use their phone was echoed by other parents who said that without giving permission, "he cannot accept that; cannot allow" his child to use his phone [SP10]. When we probed deeper to understand this, many parents in Soubré described their concerns about children's lack of respect for parents and for phones. Some said simply that "when they use the mobile, they do not respect the parents" [SP10]:

*"The child takes the dad's units to call others, the dad is coming now, he wants to call the village, he sees there are no units, who has removed them? It is the child who took the phone."* [SP10]

This parent describes his concern that children will use all of the "units" (or, airtime) on the phone without the parent's permission. Other parents described how they feel "the phone itself is private" [SP1] and "The mobile is confidential... the phone is personal. Even my wife does not answer mine for me" [SP1]. Parents' attitudes towards other family members' access to their mobile devices clearly vary widely, and are likely to impact the usage of mobile technology for learning literacy.

### 3.5.5 Desired Contexts for Mobile Learning

Finally, we heard themes about parents' preferences for the contexts of their children's learning. To elicit these, we presented them with storyboards showing children learning on mobile devices in various contexts and followed this with questions probing their preferences and opinions of these designs. An example storyboard is shown in Figure 3-3. Some parents described wanting input into the timing of children's learning with their mobile phone. Several parents across both regions in our study described how they wanted to choose when to request a lesson on the system, saying "I will not let the system alone call me. I too must call the system." [SP5].

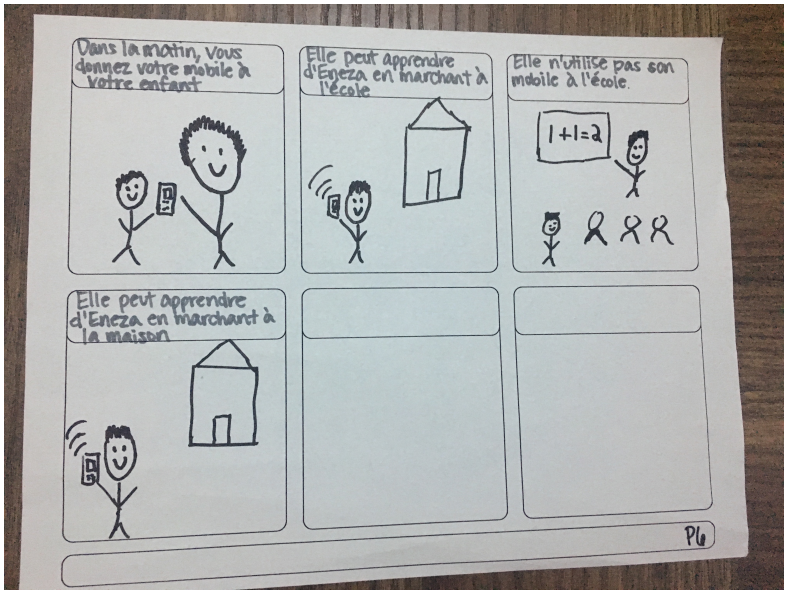


Figure 3-3: Example storyboard

Although some parents described wanting their children to use the phone at school, many parents, mostly in Adzopé, told us they preferred their children learn with the phone at home due to safety concerns that phones would be stolen from their children on the walk to school. As one parent put it, "I would prefer that the phones stay at home, because going to school with it, people will steal it" [AP3]. Or, more succinctly, "someone can snatch the mobile" [AP5] or "There are too many dangers." [AP7].

For many parents, themes emerged about their desire for the family to learn with the phone in collaborative contexts. Parents described how in their families, "those who are further ahead help those who are behind, in the lower classes" [AP2]. Perhaps because their children were already learning together in multi-age classes, when we showed parents storyboard options of children learning alone or together with a mobile device, many wanted their children to use the phone to learn together—because, as one parent told us, they did not want to "leave the others" [AP4]. As another parent put it, they wanted a group learning activity,

> *"...so that all the children are at the same level. All my children must be at the same level. There is none who can be above the others. If I have five children and show something to one, the others must also understand that thing. I have to play with them all together."* [AP6]

In addition to wanting their children to learn together on the phones so they will all be "at the same level", some parents also described wanting to learn French literacy themselves, along with their children. One mother described wanting to play a literacy game with her child so that "together they have fun - I am capable and I too want to learn" [AP3]. Another parent describes how he wants to receive instruction from the mobile along with his child because "I want to move ahead. I want to go in front. I do not always want to stay behind." [AP4], echoing the desire for "advancement" afforded by access to French literacy seen earlier. [1] However, as participants' stated preferences may not always be aligned with their actual practices, we complemented these interview questions with storyboards, in a "speed-dating" approach [61]. When shown storyboards of parents playing word games with their children, many parents preferred not to play games with their children, but most parents *did* want to monitor, direct, or be involved in their children's learning in other ways.

## 3.6 Discussion

Parents and the home environment are crucial elements of children's social ecology for early literacy learning [133, 212, 184]. Yet for families in low-resource contexts, children may lack a home environment with reading materials or sufficiently literate adults to provide stimulating literacy experiences, a situation that may be exacerbated in multilingual contexts where the language of instruction may be different from families' home language [170, 168, 107]. Mobile devices, ubiquitous in developing contexts [140], may offer one way to supplement family literacy environments via instructional technology [241, 189, 49], but they must account for parents' beliefs, attitudes, and desires for their children's literacy and use of mobile devices in order to be effectively adopted and used. As others have argued, there are complex socio-cultural, economic, historical, and political influences that intersect to impact users' experiences with technology in culturally specific ways in different contexts [251, 115, 100]. In this chapter, we highlighted some of these tensions around the history of bilingual instruction with the PEI

[1] We explore some of these design implications for supporting parental literacy in a workshop paper [146].

program and our choice to teach French literacy. See Chapter 7 for a longer discussion of these tensions in language and literacy technologies.

This chapter is one part of a "design-based research" (DBR) approach [17, 75]. As described in Chapter 2, DBR is an iterative, mixed-methods research approach, using collaborative design with multiple stakeholders to refine our understanding of a particular phenomenon-in-context. As such, the nature of the cognition in learning settings is always already intertwined with the webs of socio-cognitive relationships with other learners, teachers, parents, and others in the community and the particular socio-cultural, political, and historical context of that community [178, 203, 17], resulting in "theories-in-context" [17]. This chapter is intended to highlight the situated knowledge surfaced from our findings about the beliefs, goals, and values of parents in several rural communities in Côte d'Ivoire, which may have implications for other contexts.

### 3.6.1 Limitations and Future Work

As an exploratory study, this chapter is limited by a small sample size of participants (N=17) from two regions in one country, and as such, the findings should not be generalized without adaptation for a different population and context. Although we interviewed other community stakeholders in this study (e.g., teachers, tutors, and children), we report in this chapter primarily on parents' perspectives. In addition, in this study, our data is derived primarily from interviews, storyboard speed-dating, prototype testing, and field notes in the community, and not from extended home observations (as recommended by [225, 184]). In future chapters, we discuss home observations to understand more about home learning in this context.

## 3.7 Conclusion

Children's language and literacy are developed through interaction with others and given meaning situated in the social ecologies of learning in their lives. The family home environment is one such social ecology, and the primary one in early childhood, but many parents across the world lack the literacy to effectively support their children at home. As mobile devices become increasingly ubiquitous across developing contexts like Côte d'Ivoire, they have the potential to provide scaffolds for family support for literacy in low-resource areas where local schools struggle to reach every child.

This study provides further evidence for the importance of understanding family literacy beliefs and practices in multilingual contexts, the relationship between parents and schools, and parents' attitudes towards children's use of technology. In the next chapter, we describe Study 2, in which we developed and deployed a mobile-based literacy system inspired by these findings, using interactive voice response (IVR) and SMS to provide lessons in phonological awareness and print-sound mapping.

# Chapter 4

# Developing and Deploying a Family Literacy Support Technology (Study 2)

## 4.1 Overview

In Study 1, in spring 2018, we used interviews and storyboard speed-dating to understand parents' beliefs, goals, and desires for their children's literacy and for the use of technology to support that literacy development. Following this, I and the rest of my research team used those desires and goals to inform the design of an early literacy instructional system (described in detail in the next section). We provided that designs to Eneza Education, who implemented the system we designed in a product called Allô Alphabet. This system provides voice- and SMS-based lessons in phonological awareness and phonology-orthography mapping to children via pre-recorded audio content through an interactive voice response (IVR) system. In Study 2, in fall 2018, we deployed an early version of Allô Alphabet with 38 families in one village in rural Côte d'Ivoire. Because of the critical role played by parents and other family members in providing a supportive environment for developing literacy (see Chapter 2 and 3 for more detail), we conducted a set of 24 home observations to investigate whether and how parents and other family members were providing such support to their children using the system. Although we learned a great deal in Study 1 about how Ivorian families supported their children's education and literacy, and how they would want their children to use technology for learning, we wanted to understand what they would actually do when given such a technology.

We thus investigated the following research questions in Study 2:

**RQ2.1**: (a) What are rural Ivorian children's patterns of use of an IVR literacy system designed to foster the development of French by building phonological awareness and decoding skills? (b) What is the relationship between their usage of this IVR and their performance on the IVR lessons?

**RQ2.2**: (a) How do rural Ivorian families support their children's use of an IVR literacy system? (b) What is the relationship between that engagement and children's IVR usage?

## 4.2 System Design

We[1] designed a functioning version of a voice-based literacy system to foster phonological awareness and print-orthography mapping, and which we used as a design probe to understand how

[1](I and others on my research team at CMU; a team of neurolinguistics researchers at University of Delaware [103, 104]; and the Eneza Education team)

family members were involved in supporting children's learning with an educational technology. In this section, we describe the phonology curriculum, the system architecture for the interactive voice response system, and the mobile device provided to participants for the duration of the study.

### 4.2.1 Phonological Awareness Curriculum

Based on prior research demonstrating the importance of phonological awareness for developing a foundation for early literacy [130, 35], we target phonological awareness and grapheme recognition as the intervention in the studies in this dissertation. 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 [35, 130]. 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 [87, 260].The curriculum contains 8 units, gradually increasing in complexity and difficulty, from simple rhyme and syllables awareness, to letter-phoneme mapping, and print-syllable mappings. See Figure 4-1 for an overview of the full curriculum, with example questions provided for each unit.

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) [215], 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 [72, 44]. In this study, users only experienced the first 2 of 8 units, which ask learners to match words or syllables that share a sound or a combination of sounds, to choose the word or sound that "does not belong", and others. See See Figure 4-2 for examples of questions from the first 4 units. The specific tokens used in each question are chosen procedurally from sets of available tokens (i.e., words, syllables, or phonemes).

### 4.2.2 Interactive Voice Response System Architecture

Because our population of learners and their parents is likely to be low- or non-literate [141, 103], we implemented the curriculum on an interactive voice response (IVR) system, to provide instructions, lessons, questions, and feedback via pre-recorded voice messages, with the selection of responses provided by pressing numeric touchtones. This follows many others in the ICTD community [160, 177, 150, 192, 191] in using IVR for designing for low-literate users (see Section 2 for a review). To develop the IVR interface and back-end, and to implement the IVR on the local Ivorian telecom networks, we partnered with a local education technology company, Eneza Education, based in Kenya, with an office in Abidjan, Côte d'Ivoire, who worked with an Ivorian mobile network operator (MNO), MTN. The users call in to a specified number, which is received by a "SIP" (Session Initiation Protocol) trunk, which immediately ends the call and calls the user back (to avoid fees for the user's account. Once connected, we identify the user from the phone number they are calling from, and retrieve the relevant data on that user's progress from the database. See Figure 4-3 for a visualization of the system architecture.

Our system provides instructions, questions, and feedback via voice messages recorded in French[2] by an Ivorian student researcher on our research team. See Figure 4-4 for an example

[2]See chapter 7 for a discussion of the use of local language.

| Unit | Topic | Modality | Example (French) | Example (English) |
|---|---|---|---|---|
| 1 | Knowledge of rhymes | Auditory | 'coin-pain' vs. 'coin-col': Ces mots riment-ils? | Do these two words rhyme? |
| 2 | Knowledge of syllables | Auditory | 'pa', 'ma', 'tu': Lequel ne va pas avec les autres? | Which does not belong with the others? |
| 3 | Knowledge of phonemes | Auditory | 'ch', 'a': Quel mot font-ils? 'chat' or 'sa'? | What word do these sounds make? |
| 4 | Simple letter-phoneme mapping | Auditory+visual | Regarde cette lettre. Quel son fait-elle? /n/, /m/, /t/? [SMS]: 'm' | Look at this letter. What sound does it make? |
| 5 | Complex letter-phoneme mapping | Auditory+visual | Quel mot ne contient pas le son /s/? [SMS]: 1. dos 2. passe 3. son | Which word does not contain the sound /s/? |
| 6 | Print-rime mapping | Auditory+visual | Les mots dans une des paires suivantes terminent en le même son. Quelle paire? [SMS]: 1. pain, bain 2. pain, cas | The words in one of the following pairs end in the same sound. Which pair? |
| 7 | Print-simple syllable mapping | Auditory+visual | Ces deux sons font un mot. Quel mot font-ils? /l/, /a/. [SMS]: 1. les 2. la | These two sounds make a word. Which word do they make? |
| 8 | Print-complex syllable mapping | Auditory+visual | Ces deux sons font un mot: /ʃ/, /a/. Quel mot font-ils? [SMS]: 1. cas 2. chat | The two sounds make a word. Which word do they make? |

Figure 4-1: Phonological Awareness Curriculum

| Unit | Question Number | Question Example |
|---|---|---|
| 1 | 1 | "Which word ends in /o/? *pause* [bo], [dõ], [li] *pause* Press 1 for [bo], 2 for [dõ], or 3 for [li]." |
| 2 | 2 | "Which one ends in /o/? *pause* [ko], [zõ], [gi] *pause* Press 1 for [ko], 2 for [zõ], or 3 for [gi]." |
| 1 | 3 | "Which word doesn't go with the others?" *pause* [bo], [fo], [si] *pause* Press 1 for [bo], 2 for [fo], or 3 for [si]." |
| 2 | 4 | "Which one doesn't go with the others?" *pause* [go], [ko], [zi] *pause* Press 1 for [go], 2 for [ko], or 3 for [zi]." |
| 1 | 5 | "Do the following words rhyme? *pause* [ta], [ma] *pause* Press 1 for Yes, 2 for No." |
| 2 | 6 | "Do the following syllables rhyme? *pause* [go], [ga] *pause* Press 1 for Yes, 2 for No." |
| 1 | 7 | "Which pair rhymes? *pause* [pɛ̃], [mɛ̃] *pause* [pɛ̃] [põ] *pause* Press 1 for [pɛ̃],[mɛ̃], or 2 for [pɛ̃], [põ]." |
| 2 | 8 | "Which pair rhymes? *pause* [go], [ga] *pause* [go] [lo] *pause* Press 1 for [go],[ga], or 2 for [go], [lo]." |
| 3 | 1 | "Listen to these words. Which one doesn't go with the others? *pause* [tõ], [ta], [li] *pause* Press 1 for [tõ], 2 for [ta], or 3 for [li]" |
| 3 | 2 | "Listen to these syllables. Which one doesn't go with the others? *pause* [te], [ta], [li] *pause* Press 1 for [te], 2 for [ta], 3 for [li]." |
| 3 | 3 | "What sound does the word [ʃa] start with? *pause* Press 1 for /ʃ/, 2 for /k/, or 3 for /s/." |
| 3 | 4 | "What sound does the syllable [za] start with? *pause* Press 1 for /ʃ/, 2 for /z/, or 3 for /s/." |
| 3 | 5 | "What sound does the word [ʃak] end with? *pause* Press 1 for /ʃ/, 2 for /k/, or 3 for /s/." |
| 3 | 6 | "What sound does the syllable [tin] end with? *pause* Press 1 for /ɲ/, 2 for /n/, or 3 for /m/." |
| 4 | 1 | "What word starts with the sound /d/?" |
| 4 | 2 | "Look at this letter. Which sound does it make? /d/, /b/, or /f/? *pause* Press 1 for d, 2 for b, and 3 for f." |
| 4 | 3 | "Look at these letters. If we put them together, what sound do they make? Press 1 for /ʃ/, 2 for /ɲ/, or 3 for /ã/." |
| 4 | 6 | "One of these spellings makes the word /vu/. Which one is it?" |
| 4 | 7 | "Which letter makes this sound? *pause* /l/." |
| 4 | 8 | "Look at these syllables *pause* Which one does not contain the /z/ sound?" |
| 4 | 9 | "Listen to these three words: /ra/, /ri/, /do/. *pause* Which one does not contain this letter? *pause* Press 1 for /ra/, 2 for /ri/, or 3 for /do/." |
| 4 | 10 | "Listen to these three syllables: /ti/, /ki/, /lo/. *pause* Which one does not contain this letter? *pause* Press 1 for /ti/, 2 for /ki/, or 3 for /lo/." |
| 4 | 11 | "Which starts with the sound /f/?" |
| 4 | 12 | "What sound does this word start with *pause* /d/, /k/, or /g/? Type 1 for /d/, 2 for /k/, or 3 for /g/" |
| 4 | 13 | "Which word starts with the sound /b/?" |

Figure 4-2: Example Questions from Curriculum

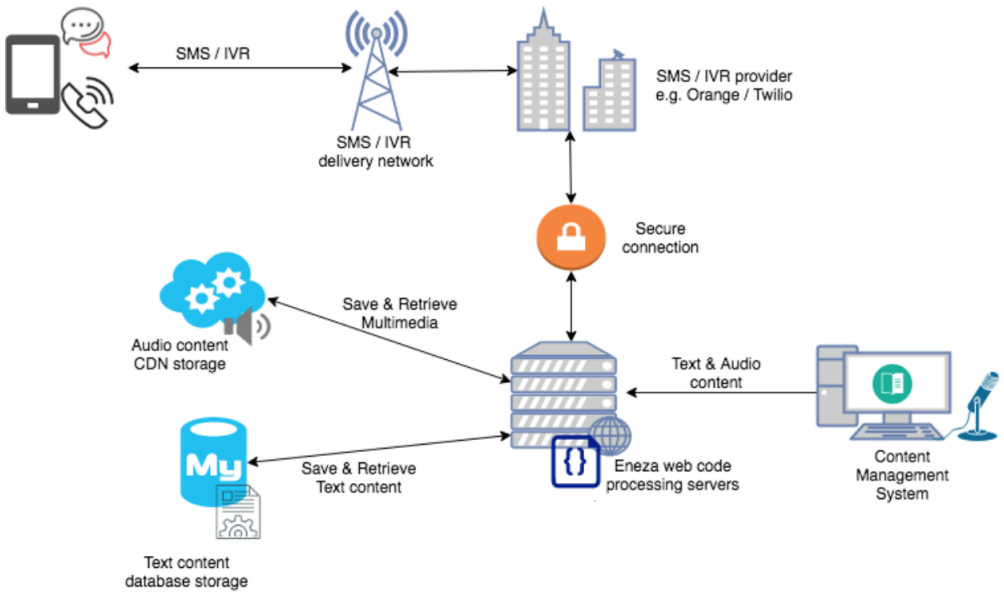


Figure 4-3: IVR System Architecture Diagram

call flow demonstrating the delivery of instructions and questions. 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, and then the student is given 5 questions of the same question type. For each question, the system plays a pre-recorded audio message with the question and response options, and waits for input from the user on the phone's keypad. If the student does not push an answer response option, the question and answer options repeat. 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. See Appendix A for the full call flow diagram.

### 4.2.3 Device Description

Although we found in Study 1 that many families in rural communities in Côte d'Ivoire possess mobile devices already, with some families having multiple devices per family, we chose to provide a mobile device for the duration to the families participating in Study 2. Because the intervention is based on IVR voice messages and SMS messages, we wanted to ensure that there was no impact on the students' experience of the content due to differences in the devices their parents owned. Further, because many families expressed in Study 1 that they would not feel comfortable with their children using their personal device, due to the chance for misuse of airtime credits or other content on the device, we wanted to provide a device for the sole purpose of calling to receive lessons, thus ensuring that the device would be available when children needed to use it to call.

We chose the Itel IT5231 mobile phone - a model available in stores in Adzopé and which

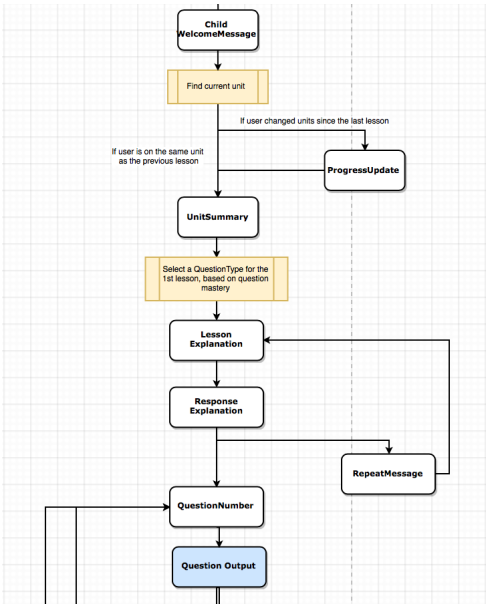


Figure 4-4: Example Call Flow

would be likely to already be owned by others in the village, who could have provided additional support if needed. It has a loudspeaker for playing the voice messages hands-free, as well as a comparably large 2.4 inch screen, and 8mb internal memory for storing SMS messages, 2G network accessibility, which is available in most parts of the region [140], and a long-lasting, rechargeable, 1900 mAh lithium ion battery. We procured 50 such devices, along with 40 SIM cards for the 38 participants, pre-registered the SIM cards, added sufficient airtime credit for the participants to call in on a daily basis for 4 weeks (with the actual cost for the calls subsidized by our funding agency, the Jacobs Foundation), and made sure that all devices were charged and able to receive IVR calls and SMS prior to the launch of the study - as seen in Figure 4-5.

## 4.3 Context

This study took place in a rural village in the Adzopé Department, a cocoa- and rubber-producing region in southeast Côte d'Ivoire. The study village had a population of 13,786 as of the 2014 census [63, 62], with speakers of Attié, Koulango, and Dioula, in addition to French. Located along the main highway from the regional center of Adzopé, there is regular foot traffic and private buses and vans that provide the main source of transportation between this village and the surrounding area. Schools in the Adzopé region have a student-teacher ratio of 45:1, and many schools lack electricity, water, or bathrooms [62]. This study was approved by the IRBs of participating universities, as well as approved by the review board of the Ivorian Ministry of Education. We met with the head of the local COGES (*Comité de Gestion d'Écoles*, or school organization committee) and village chief to obtain approval for the study and align our methods with local norms. The study took place with 38 of the 39 students from the CM1 class (equivalent to 5th grade in the US) in one randomly chosen school of the four public schools in the village. We held a meeting with parents and guardians of the CM1 students to explain the study and obtain consent to participate. We met the parents at the school, as it was a central meeting area, and the school directors assisted us in meeting parents at the school. However,

Figure 4-5: Itel IT5231 Mobile Phones

we explained to parents that the study would take place at home, and they were not required to participate. The study lasted for five weeks, from October 25th to December 1st, 2018.

## 4.4 Study Design

As the second phase in a design-based research methodology, we deployed the voice-based literacy system described above with 38 children for seven weeks, and collected quantitative data of children's system usage and learning performance, as well as collecting qualitative data from observations of 24 families using the system at home.

### 4.4.1 Assessment, Survey, and Phone Training

A pretest was administered at the start of the study to establish a literacy baseline. The pretest included items on phonological awareness in French and Attié, the primary local language, such as identifying the initial or final sounds of words (e.g., "jour /j/"), removing the initial or final phoneme of words and identifying the subsequent word (e.g., "neuf - /n/ = oeuf"), and items on phoneme and syllable segmentation. The test also included a basic assessment of French reading skill through grapheme identification (e.g., "what is the name of this letter or group of letters? "ch"), reading common words (e.g., "mal"), and reading invented words (e.g., "tipa"). Prior to the start of the study, we gave a one-hour training for caregivers of all participants, explaining the purpose of the study, distributing the phones, and teaching them how to call and complete lessons. Though we showed the adults how to call, we did not explicitly instruct them to assist their children.

Table 4.1: Information on Adults Interviewed

| ID | Adult Role | Job | Language |
|---|---|---|---|
| 1 | Father | Cocoa farmer | French, Attiè |
| 2 | Father | Teacher | French, Attiè |
| 3 | Father | Cocoa farmer | Attiè, French |
| 4 | Sister | Cocoa farmer | Morè, French |
| 5 | Mother | Cocoa farmer | Attiè |
| 6 | Father | Cocoa distributor | Attiè, French |
| 7 | Mother | Cocoa farmer | Attiè, French |
| 8 | Mother | Cocoa farmer | Attiè, French |
| 9 | Mother | Cocoa farmer | Dioula, French |
| 10 | Mother | Cocoa farmer | Koulango |
| 11 | Brother | Cocoa farmer | Morè, French |
| 12 | Father | Cocoa farmer | Attiè, French |
| 13 | Father | Cocoa farmer | Attiè, French |
| 14 | Mother | Cocoa farmer | Koulango, French |
| 15 | Mother | Cocoa farmer | Attiè, French |
| 16 | Aunt | Cocoa farmer | Attiè, French |
| 17 | Sister | Cocoa farmer | Koulango, French |
| 18 | Brother | Tailor | Koulango, French |
| 19 | Aunt | Tailor | Koulango, French |

During this seminar, we also administered a brief survey to understand more about participants' home environment, such as family members' occupations, literacy, proxies for socioeconomic status, and more (not all of which are reported on here). The primary employment of most families in the study was cocoa farming (26/38), though there were also sellers of fish or vegetables (7/38), two tailors, a teacher, and a cocoa distributor. These families were distributed across the village, with some located quite near the school, and others several kilometers away, with some living in minority language communities, such as Koulango and Dioula. Most families spoke French in addition to their mother tongue, though two spoke only Attié and two only Koulango.

### 4.4.2 Home Observations and Interviews

Our team of an HCI researcher and a linguistics graduate student from Coôte d'Ivoire who spoke several mother tongues visited 24 participants at their homes for 3 of the 5 weeks of the study, to observe how the children and their families used the IVR. We called each family to schedule a time to visit, and only 24 (of the 38 participants in the study) were available. Half of the observed participants were boys and half girls. During the visits, we interviewed an adult guardian and observed the children calling the IVR. We interviewed 19 adults in total, for 24 children, as some families had multiple children participating.

In each visit, we explained that we wanted to observe the normal scenario of calling and completing the lessons, to the extent possible, though there was likely some effect of the two researchers observing. We took careful notes (and recorded video) of how the child used the system and how the adults present interacted with the child. We asked the adults questions about how and why they helped their child learn - in ordinary circumstances as well as with the IVR - and questions about their beliefs and goals about education and French literacy. Each

interview and observation was nearly an hour, totaling nearly 20 hours of video data.

## 4.5 Findings

### 4.5.1 Children's Use of Literacy IVR (RQ1)

First, to investigate children's use of our IVR literacy system, Allo Alphabet (RQ1a), we used call detail records logged for all interactions of 36 users for the five weeks of the study (1 phone was used by two children, and we thus removed those participants from these analyses). We find that each student called in for a mean of 14.2 days ($SD$=7.4) of the 38 total days of the study, with one student initiating calls for 32 days, and one calling for only one day. On average, users initiated 81.4 calls across 5 weeks ($Med$=68.5, $SD$=59.6, $min$=1, $max$=337). The usage was relatively constant during the week, with a slight increase on Fridays, averaging 104.2 calls each Friday ($Med$=67.0). On all days, the majority of calls were around 6-7pm (GMT), though students did call in throughout the day, from 6am until 10pm (Figure 5-6). On average, students spent 6.2 minutes on the calls ($Med$=4.9, $SD$=4.3), with one student spending an average of 1.2 minutes and one with an average of 20.4. We had originally estimated that children should spend 20 minutes on the call, if they were completing 10 questions and spending roughly 2 minutes on each. However, this assumption was not borne out. Across all calls, users attempted an average of 302.4 questions ($Med$=193, $SD$=233, $min$=3, $max$=890), and correctly completed 44% ($SD$=6%, $min$=33%, $max$=62%) of the questions on the first attempt (as hints are given on later attempts). If students would have guessed randomly, they would have been correct 37% of the time.

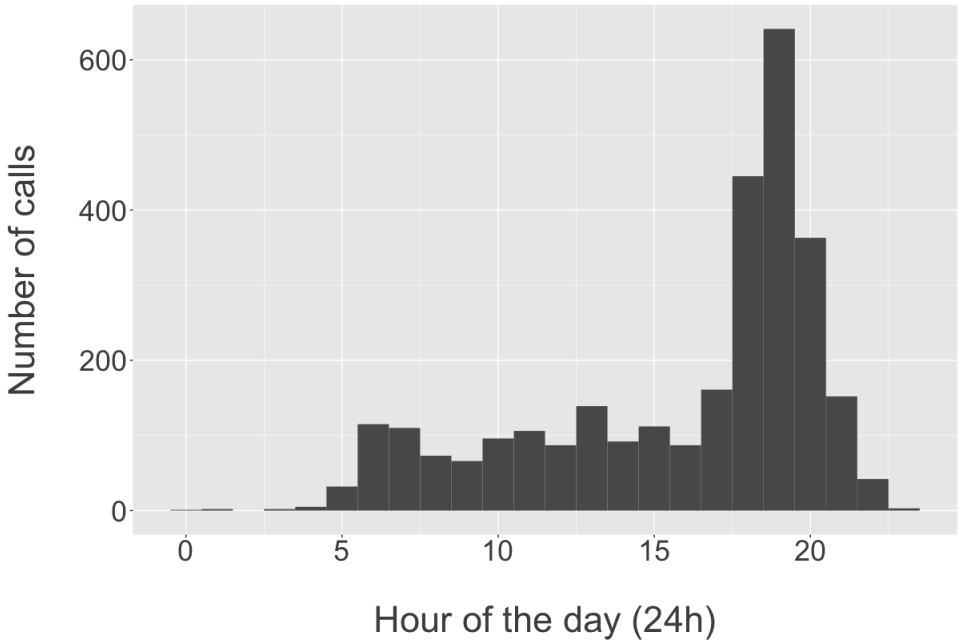


Figure 4-6: Distribution of IVR call times

To investigate the relationship between children's usage of Allo Alphabet and their phonological awareness (RQ1b), we use two features from the call detail record data (call frequency and call duration), as well as their performance data on the pre-test and the IVR question items. We conduct two regression models with students' percent of questions correct on their first attempt

as the dependent variable and with their pre-test as a covariate for both. For one model, the total number of users' calls to the IVR was the independent variable (IV), and for the second model, the IV was the duration of calls to the IVR. There was no significant correlation between the IVs used in each model. We hypothesized that students who called more and students who spent longer on the calls would answer more questions correctly, particularly for students with a greater score on the pre-test.

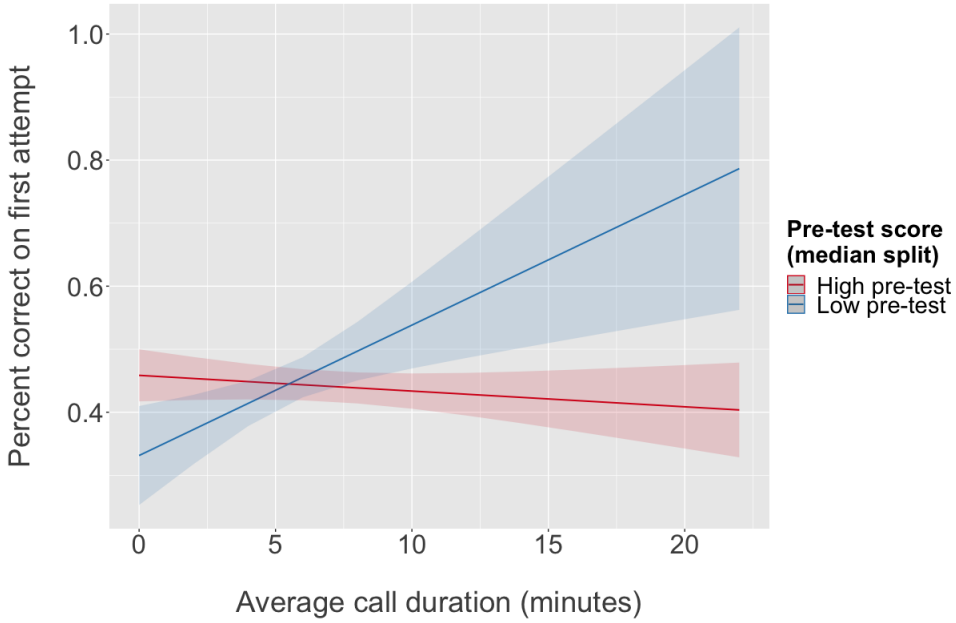


Figure 4-7: Interaction effect of pre-test and call duration

We find that there is a significant, positive relationship between the total number of calls a user makes to the IVR and the percent of questions they answer correctly on the first attempt ($F(3,30)=1.41$, $p<0.05$, adj $R^2=0.04$). That is, children who made more calls answered more questions correctly on the first attempt. However, no direction of causality is intended by this formulation. It may be the case that children who answered more questions called more. For the second model, we find that there is a significant interaction effect between the duration of the IVR calls and users' pre-test score, on the percent of questions they answer correctly on the first attempt ($F(3,30)=3.56$, $p<0.005$, adj. $R^2=0.19$). Students with a lower pre-test who spend longer on the calls answer a greater percentage of questions correctly on the first attempt than students with higher pre-tests (see Figure 4-7).

### 4.5.2 Family Support for Children's IVR Usage (RQ2)

Then, from the home observation and interview data, we identified several key insights about how children use the IVR at home. We used inductive thematic analysis methods adapted from grounded theory [221], described in more detail in Chapter 3.

At a high level, we find that many children in our study had support from other members of their family in using Allo Alphabet. Of the 24 participants we observed and interviewed at home, we saw family members of 17 of those participants providing support during the lessons, 14 of whom explicitly told us that this support was provided regularly during other times they used the IVR. The remaining 7 participants told us that no one else at home provided support

for the IVR, with some of those telling us that there was no one at home who *could* help them if they needed it. For children with support from other members of the family, we find that (1) many of these families leverage support networks with distributed roles and responsibilities for supporting their children's use of an educational IVR; (2) these adults provide various types of implicit and explicit support for children's literacy learning with an IVR, and (3) children in families with adult support attempt fewer questions, but answer more of them correctly than children without such support. We discuss each of these in more detail in the following sections.

**Family Support Networks**

First, we find that many families leverage extended support networks for their children's learning, with different support roles played by different family members at different times. These support networks were often comprised not only of the children's parents (13/24), but also other adults such as the aunt (2), uncle (2), and grandparents (1) who lived in the household or nearby, and older siblings (6) or near-peers (2), and occasionally adult neighbors (1). In our pre-study survey of all 38 participants, 32 of 38 children reported having someone in the family who can read, but only 12/38 reported that one of their *parents* could read. 26/38 said one of their siblings could read, while 15/38 said one of their extended family members could read.

These support networks involved a variety of different supporters, who had a variety of motivations for providing support for the IVR, and who leveraged a range of skills and literacies. First, we find that these family supporters help due to a sense of responsibility for the child's welfare and development. As several adults told us, they are helping "for their [sibling's] good tomorrow" (P11, older brother) and so that "they will be able to evolve, to know many things" (P16, aunt). We find that families construct and leverage these support networks to compensate for gaps in other sources of support for their children's learning, due to limitations in availability or literacy of other members of the family. As several participants described, their work in the fields required that adults leave home for several days at a time: "There is no one here. His sister is in Adzopé. Everyone goes to the field, and we are only two here" (P8, mother).

Although we heard from a small number of parents that they paid for a home tutor (*mâitre du maison*) to help with schoolwork at home (as we saw in our previous work in this region in Study 1 [148]), here we saw evidence that older siblings took on informal tutor roles to help with the IVR lessons, either because the family did not hire a tutor, or the tutor did not help with the IVR. We observed direct evidence of these informal sibling tutors in 6 observations, and were told about informal sibling tutors with 10 others, of the 24 participants observed. One sibling told us that he began helping with the IVR lesson because the home tutor was unavailable, saying "It's not like I know anything about it, but since their tutor is not there... you have to [use the IVR] in front of me" (P11, older brother). This sibling acknowledges that in spite of gaps in his own knowledge, he is helping with his siblings' IVR lessons. These informal tutors worked either one on one or with groups of children, in some cases from multiple families (Figure 4-8). "He is my nephew. She is my neighbor's child. Since it's not far, I said they just have to come here." (P11, older brother). These family supporters describe helping in spite of limitations in their literacy. Several of these supporters described their difficulties, saying they had trouble with "Words that rhyme, words that do not rhyme. It's there that I got stuck" (P4, older sister), while others want to help "with the little that I know" (P16, aunt).

In light of this evidence that even the designated helping adult may not have a complete mastery of the content, our participants articulated a philosophy of mutual support and bootstrapped knowledge sharing among members of the family. Many adults (10/19) described how others in the family help their child use the IVR because adult family supporters believe in

Figure 4-8: Older sibling working with a group of children

the importance of sharing knowledge with others. One mother said, "because if you do not understand [something], the other could." (P7, mother). Similarly:

> *"What I do not know, you [might] know. What you know, the other does not know, and you give a little of yourself. He can know [question] one, but he does not know [question] two, and you might know 2, but you do not know 1. If I show you, you show me."* (P11, older brother)

These adult supporters articulate a philosophy for mutual support, where one can "give a little of yourself" to help others and compensate for one's lack of knowledge by learning collaboratively. In fact, he later told us how his youngest brother, the participant in the study, was the one who initially showed *him* how to use the phone to dial the IVR. In other families, this collective support from others took the form of near-peers assisting the adult in teaching the participant, either helping the adult hear and understand what the IVR is saying by repeating it aloud for the adult, or helping the adult write content on the chalkboard. One mother told us how her son (only one grade above the participant) helped her daughter learn with the IVR, because "he's stronger than me. Because I left school a long time ago." (P10, mother).

Although other members of the family may support the child using the IVR, these family members are not always consistently available to support, occasionally limiting children's access to the IVR entirely. We heard from one child who told us that she never used Allo Alphabet alone, but the sister she normally worked with was often in Adzopé (P14, participant), and her parents would not let her use the IVR without her older sister. This was echoed by another child who told us that the person who helps her with the IVR goes to school in Adzopé, and is only home on weekends (P5, participant), so she only called on weekends. In other cases, sometimes even if the adult was present and available, they told us they might be too tired after

work to help (P9, mother), or they may have other responsibilities that impact their ability to focus on the child with the IVR, such as caring for younger children or preparing dinner, which we observed during multiple sessions. As one mother described, "If on the working days she needs help during my cooking time, she will sit and continue by herself" (15, mother).

### Methods of Adult Support for Children's IVR Usage

From observations of 24 children using the system at home, we identified several key ways in which adults support their children's use of an IVR literacy system at home - they (1) structure and arrange the conditions for learning; (2) provide explicit instructions for using mobile phones; (3) model and guide children in using the IVR; (4) provide explicit literacy instructions; and (5) offer socio-motivational support.

For some (10/19) parents, one major way they support their children's use of an IVR literacy system is by structuring the context and environment for their children's learning. For some, this involves the adult deciding when and where children should call in for the lessons, reminding children to start the lessons for that day, or telling them when to finish the lessons. Two children did tell us they were the one to decide when they used the phone to call for lessons, but this was a rare exception (2 of 24 children). Others made sure the environment was conducive to learning. In many sessions, there were large numbers of other children nearby ($M$=4.3, $SD$=3.2, $max$=12). Although this may have been due to our presence as guests, when we asked, many of the adults told us this was normal. To mitigate these distractions, adults would quiet the younger siblings, wave other children away, or keep other children occupied during the lesson to not distract the child using the IVR. For families where this did not occur, we observed children struggle to hear the recorded voice of the IVR in often-noisy environments.

In addition, adults support their children's use of an educational IVR by providing explicit support or control of the mobile phone. In our preliminary survey, we found that all 38 families owned at least 1 basic phone ($M$=2.2, $SD$=0.76, $max$=3), with 3 families owning a touchphone in addition to their basic phone(s), much like we saw in Study 1. Several (7/24) children told us that they had previously used their parents' phones, mostly for games or calling other family members. In this study, we find that adults often supported IVR usage by turning the phone on, finding the contact for the IVR in the contact list, dialing the IVR, answering the callback, and occasionally turning on the hands-free speaker. Some adults (7/19) dialed the IVR themselves, and then passed the phone to the child to respond to questions, while others (5/19) allowed their child to dial, but took the phone back to re-dial it if needed.

In addition to the mobile phone support, some adults supported by guiding children on how to effectively listen and respond to the IVR lessons. While some children appeared to listen thoughtfully to the IVR instructions, questions, and answers before responding, others appeared not to listen before responding. Some children (4/24) pressed the button to respond before all the answers had been listed. To address this, adults guided their children in listening carefully to the lessons (10/19), with some adults telling children to listen, think about the response options, and then respond, saying "Listen carefully; understand first before pushing. Before you press you have to listen." (P11, older brother). Many other adults echoed this admonition to "Listen to what she [the recorded IVR voice] tells you, listen carefully." (P12, father). Other adults started by listening to instructions and questions themselves, either holding the phone to their ear, or directing their child to put the phone on hands-free so they could hear, as in one father who told his daughter that "we too will listen to what she says" (P12, father). We observed many other adults modeling this type of focused listening by sitting with their child and leaning in closer to hear the IVR voice. In some cases, the adults guided their child's listening on the

phone using nonverbal cues, such as motioning them to put the phone to their ear, or putting their hand on their child's arm to indicate they should wait to respond.

Adults also prompted children to respond, either by pressing the response button, verbally repeating the answer to the adult, or even, in some cases, writing the correct responses on chalkboards. We observed one father tell his daughter, "You have to listen carefully. Which one is the right answer among these three words?" (P12, father). On some occasions, the adults would repeat the questions to make sure their child heard it, and would prompt their child to repeat the question. In some cases, the adults would write the response options down, either on a chalkboard (e.g., Figure 4-9), on paper, or with a stick in the dirt. While less frequent than other types of support, some adults (9/19) provided explicit instrumental support for the IVR lessson content. One sibling told the two children with her to turn off the IVR, wrote three response options, and asked them to say which word ended with 'ar' (P4, older sister, Figure 4-9). However, this requires that the adult be sufficiently literate herself, and to choose the right concepts. One sibling explained the concept of multiple choice questions (names anonymized):

> *"Tutor: If I say between "N'Guessan" or "Blanche", between one or two, which one is Blanche? Blanche: Two. Tutor: Good job, you did well."* (P11, brother)

Figure 4-9: Older sister writing examples on a chalkboard

To elicit this instructional support, some children directly asked their parents or adults for help with the lessons, while for others the adults offered this help without being asked, when the child appeared to need it. We observed some children handing the device over to the adults for support, both for IVR and for lesson support. One older sister told us how her siblings asked for her help, saying, "They force me to come to the phone, because nobody understands." (P4, older sister) However, not all children asked for help, even with an adult sitting next to them. One adult told us she helps "when she has a worry or... when you see that it's too hard for her or she repeats... it's when she's stuck that we help her" (P10, mother). However, this requires that the adult is present during the lesson and able to hear and understand the negative feedback provided by the system, which may not always be the case. Adults also offered encouragement or

motivation to children as they progressed through lessons. An older sibling echoed this, saying, "I'm not going to teach them every night, but I encourage them. In fact I'm a support, from one point of view." (P11, older brother). For him, his role as "a support" involved providing encouragement.

**Effect of adult support on IVR usage and learning**

Finally, given all of the different ways that adults provided support, we wanted to investigate the effect this support might have on children's IVR usage (RQ2b). To investigate this, we created a binary variable of whether each child was one of the 14 participants who we observed with adult support during the IVR lesson, *and* who told us that this support was regular and consistent for the previous lessons - or whether they were one of the 6 participants who we observed with *no* support during the lesson, *and* who told us that they had no one who they could get support from (4 participants did not meet either of these criteria). We hypothesized that children with family support would call more often and would perform better on the questions than children without such family support. However, there was no significant difference in the number of calls children made to the IVR in families with ($M$=100, $SD$=76.9) and without ($M$=94.5, $SD$=49.5) adult support ($t(15)$=0.22, $p$=0.83). There was, however, a large, though non-significant, difference in the number of questions attempted by children in the two groups, with children in families who we observed with support attempting fewer questions ($M$=295.6, $SD$=239) than those without observed support ($M$=457, $SD$=282.9), $t(8.2)$=1.22, $p$=0.26. Finally, children in families *with* support correctly completed a greater percentage questions on average ($M$=0.47, $SD$=0.07) than those without such support ($M$=0.43, $SD$=0.03), though this difference was not significant ($t(17.9)$=1.86, $p$=0.08). Thus, the (non-significant) difference in number of questions completed with the adult supporter may have been due to the supporters taking time to explain the concepts in the questions, which may have led to the (significant) increase in percent correct for children with supporters. However, the sample sizes included here may be too small to robustly identify significant group-level differences. In Study 3 and 4, we further investigate the role that these family members play in motivating and supporting children's use of our literacy technology, Allo Alphabet.

## 4.6 Discussion

In low-resource contexts with low adult literacy, educational technologies may offer one opportunity to address gaps in children's literacy that may impact their future educational attainment. However, such technologies are often designed for the child alone [127, 121, 174], or other such approaches require adults be literate to support their child's use of the system [189, 256, 68] (although see [252, 253, 250] on engaging bilingual parents). Additionally, in contexts where adults' support for children's education [199] may look very different from parental support previously identified in Western contexts (cf. [212, 136, 133]), which forms the basis for much educational technology that engages parents, these technologies should be designed accordingly. See Chapter 7 for a longer discussion of these implications.

In our prior work in rural communities in Coôte d'Ivoire, described in Chapter 3, we identified adults' beliefs and practices around children's literacy [148]. Then, based on those findings, we designed an IVR system to foster children's phonological awareness, Allo Alphabet, and deployed it with 38 participants in one village in rural Coôte d'Ivoire, for 5 weeks. Our goal in this deployment was to understand how children would use an educational IVR, and how families would engage with children's IVR use. We find that many participants called in regularly to

respond to questions, with their correctness on those questions positively associated with their amount and duration of calls, and with learners with lower prior knowledge who spent more time on the IVR completing more questions correct on the first attempt. We find that the majority of participants we observed used the IVR with support from other family members, and children who had such support correctly completed more questions on average. This system deployment also served as a *design probe* (cf. [95]) with which to understand family engagement with an educational technology used at home.

### 4.6.1 Distributed Educational Support Networks

We find in this study that families in rural communities in Côte d'Ivoire often leverage support networks of multiple adults and siblings (i.e., not only the parents) to support children's literacy with an IVR. In fact, this practice of leveraging other family members to support children's literacy was echoed in our prior work in Study 1, where parents told us that, in their families, many people each contribute to support children's literacy in different ways [148]. In this study, we see evidence that this is not only a belief held by parents, but it is enacted in the lives and practices of families using educational technologies.

Although many parents in our study did not have sufficient literacy themselves to support children's literacy in the explicit, instrumental ways described by prior literature—such as letter naming, book reading, etc. [212, 78, 136]—parents leveraged multiple actors in their family network to support their children through a variety of literacies, both print and digital. These supporters often provide other types of support beyond instructional content support, from structuring the conditions and environment for learning, communicating the value of literacy, and procuring resources (e.g., chalkboards, notebooks, and private tutors), to teaching children how to use the mobile phone and IVR. This echoes what Barron et al. and DiSalvo et al. describe as the multiple roles that parents play in their children's learning, such as learning brokers, resource providers, and monitors [67, 21]. However, unlike prior work, we see here that these roles are not played only by parents at different times, but in our context are distributed across multiple actors in family support networks.

We did not find the hypothesized positive relationship between children's prior phonological awareness (as assessed on the pre-test) and their successful completion of the language lessons on the IVR. This suggests that there may be moderating factors at work, such as children's ability to operate the phone or understand how to respond to IVR questions, or other differences between the pre-test and the IVR items. We observed many children who responded to questions before the responses were listed, or who were unsure how to answer a multiple choice question. To address this, many family supporters provided device and IVR support, helping children call the system, and helping them understand how to press the touchtone to select responses to multiple choice questions. The support for device and IVR usage (broadly, digital literacy) may thus have contributed to the increased question performance for children with adult support compared to those without it. Many supporters who were not themselves literate were observed using their own mobile device for calls, as well as recognizing and selecting the Allo Alphabet contact in the children's phones. In fact, while the adult literacy rate in Côte d'Ivoire is less than 50%, mobile phone penetration in Côte d'Ivoire is over 130%, with every family in our study owning at least one phone.

This suggests that, in addition to prior work that found that literate intermediaries help low-literate users operate mobile devices [204], we find in this study that digitally literate adults may be able to support children's mobile device and IVR usage, despite lacking the French literacy knowledge to help with the content. However, not all adults in the study provided digital

literacy support, despite the potential for them to do so. This suggests that future educational technology designers may design interventions to nudge adults to support their children with using the phone or IVR if it appears from the log data that the child is having difficulty using the IVR appropriately (e.g., pushing numbers that are not options, or responding before the audio is complete). Although, given that children in our study who had such support attempted fewer questions, though correctly completed more questions overall, than children without such support, care should be taken to scaffold adults to phase out such support when it is no longer necessary, to allow the child time to actively complete more lessons on their own.

Although these family support networks provide flexible coverage on various support roles, they may introduce communication and coordination challenges. These support networks are complementary, distributed, and flexible, with adults taking on support roles due to gaps in support from others in the family. This flexibility is in some cases a strength, as when older siblings take on informal tutoring roles when the formal tutor is unavailable. However, there may be breakdowns in the communication among these family members, potentially impacting the uptake of the system. For instance, when some families sent an adult to the initial launch of the study to be trained how to use Allo Alphabet, this adult in some cases did not tell the other adults at home about the purpose of the study or how to use the IVR. Some families thought the phone was a gift for their child performing well in school, while others did not know that it was meant to be used for calling to receive lessons. For some families with communication issues, the adult who attended the information session simply failed to tell the parents about the purpose of the study, while others tried to inform them, but weren't able to explain how to use the IVR.

This suggests that designers of scaffolds for adult support for children's educational technology usage should design for the potential to have multiple supporters, operating asynchronously, who may not communicate among themselves regularly. This might entail sending SMS or automated voice calls to each supporter who is associated with the child. Further, as some adults might be better able to support the child in different ways, designers of adult support scaffolds might infer or detect the type of adult supporter (e.g., supporter for device or IVR usage, supporter for instructional content) based on their patterns of activity, and suggest personalized support based on that role. Additionally, for educational technology deployments in rural, low-resource contexts, this suggests that additional communication methods might be needed to communicate about the purpose of research studies, such as broadcasts on community radio, or the use of a town crier (*griot*), which we employed for this purpose in Study 3 and 4.

### 4.6.2 Collective Intermediation in Educational Technology

Prior research on technology use in low-resource, low-literacy contexts has highlighted the role that technology *intermediaries* play in supporting the primary user, or beneficiary, in their use of technology [204, 113, 164]. We find evidence in this study for a collective approach to intermediation for educational IVR, through family support networks where supporters may not be more literate than the beneficiary user, but where each person supports in different ways, via this collective network of intermediaries with different skills. The members of these family support networks describe being motivated out of a sense of shared responsibility for the child, not for reputation or social capital (as in [204]), and they balance between active and passive support roles as needed, rather than the primarily active role of intermediaries for information-seeking technologies [204, 113, 164][3] These findings are aligned with findings from

[3]See Chapter 5 for a more thorough discussion on caregivers' motivations and their active and passive support for learning with Allô Alphabet.

prior ethnographies of care and support in Côte d'Ivoire, which identified how families develop mutual support networks for family members with health or financial difficulties [142, 33]. This suggests design opportunities for leveraging such collective, distributed intermediation for other sectors, such as family health [180, 22] or finance [159].

Although the Allo Alphabet IVR was designed for a single user, adult supporters adapted their usage of it to fit their desire for collective support for children's learning, much like other ICTD work on users' appropriation of technologies beyond the intended usage [213]. We find that adults engage in both simultaneous and sequential use of the IVR with their child. We heard from many families who valued children learning collaboratively, and we saw cases where the adult worked with multiple children at the same time, either sequentially, with children observing the others using the system while waiting to call in themselves, or simultaneously. These simultaneous learning scenarios meant the adult could direct a group of children's attention towards a shared resource (often a chalkboard) to provide instructions to all. Unfortunately, this also meant that the audio of the IVR often continued playing in the background, which was potentially distracting.

This suggests that designers of educational IVR should design affordances for the collective nature of technology use at home, with multiple learners using the system in the same place sequentially or simultaneously, and possibly in the presence of an adult supporter who may support the IVR usage synchronously or asynchronously via offline instruction. The adults in this case might also play the role of co-learner or collaborator (as in [67, 21]), where they may develop their own literacy abilities by scaffolding children's responses to questions. In addition, for adult supporters with sufficient literacy to provide instructional support (as in the sibling teaching the rhyming skill on the chalkboard), the types of skills and example words the adult chooses to teach may not be what their children actually needs the most support with. An educational IVR might thus provide messages to the adult supporters with personalized support suggestions. Further, given the challenges of simultaneous engagement, educational IVR might provide asynchronous components to support offline activities or games, to leverage the benefits of collaboration while not distracting children with simultaneous audio messages, or allowing the adult to pause the IVR while they provide offline support.

More broadly, this collective intermediation has implications for technology—particularly education technology—designers to understand and design to scaffold the social context around technology use. Although many of the families in this study were able to provide such support, many others may not have been able to. We were not able to speak with 14/38 families in the study, despite repeated attempts to contact them, due largely to those family members working out at the farms outside of the village, where cell service was not available, or who would not be back in the village to meet with us. This suggests that our understanding of the nature of this family support may be skewed by the perspectives of those who had family members available. See a larger discussion of these issues of designing for social context and of potentially inequitable distribution of participation in the research in Chapter 7.

### 4.6.3 Limitations

First, the primary limitation of this study is the small sample size (38 participants in one school), which we rectify in subsequent studies in the next two chapters. Although we observed our participants use the IVR in a natural setting by visiting their homes with a local collaborator, our findings might be limited by *participant response bias* [65], or a potential selection bias, as the remaining 14/38 participants were not available. However, there was no significant difference in frequency of IVR usage for the 24 participants compared to the other 14. Additionally, for

the sessions we did not observe, we do not know whether the person who was completing IVR lessons was actually the child, their adult supporter, or other children. Although we have log data from 5 weeks of system usage, we only conducted one observation and interview each with those 24 participants, and thus we do not have longitudinal data on the nature and extent of support provided over time. The binary categorization we used here for whether children had support or not is a fuzzy category at best, as this support may have been inconsistent before or after our visit. Although an isomorphic post-assessment would be the ideal method to show growth in learning, complications from school holidays and teacher strikes rendered us unable to deliver a post-assessment in a timely fashion. In Chapter 4, we discuss a longitudinal study of a deployment of Allo Alphabet, which was intended to measure the learning gains in literacy from the IVR over several months (with an isomorphic post-assessment delivered at the end of the intervention).

### 4.6.4 Conclusion

Educational technologies offer one approach to foster children's literacy development in out-of-school contexts, but many such systems are designed for the child as the sole user, or are based on Western ideologies of what parental support and engagement looks like. Voice-based educational systems may provide an opportunity to leverage such support from adults of all literacy levels, but these systems are not typically designed to engage learners and their supporters. This chapter contributes to the community of researchers designing family educational interventions in low-resource contexts, by identifying ways in which family supporters of a variety of literacy levels contribute to their children's learning with an educational technology. In this chapter, we contribute evidence for the complex, multifaceted role that families play in supporting their children's learning, we identify specific ways in which adults support children's use of an educational IVR system, and we suggest potential design recommendations for designers of educational systems that may engage such family supporters.

# Chapter 5

# A Longitudinal Deployment of a Family Literacy Technology (Study 3)

## 5.1 Overview

The design research we did in Study 1 helped us to understand rural Ivorian families' beliefs and practices around children's literacy, as well as their desires and concerns for family literacy technology [148]. We then developed an interactive voice response (IVR) literacy system for fostering French phonological awareness, Allô Alphabet, based on the findings in Study 1. In Study 2, we deployed it with 38 families in one village in rural Côte d'Ivoire [145], investigated how those children used Allô Alphabet for a month, and identified ways that family members provided support for their children's use of Allo Alphabet.

In this chapter, to investigate how and why family literacy practices and engagement with literacy technology changed over time, at a larger scale, we deployed Allô Alphabet with 750 families in 8 rural communities in Côte d'Ivoire for 4 months in spring 2019. This was intended to be a randomized controlled trial, with a pre- and post-assessment to evaluate the efficacy of Allô Alphabet. However, complications due to a novel government policy requiring individual registration of all SIM cards prevented us from reaching the sample size needed to effectively conduct the endline evaluation. As a result, in this chapter, we use data from surveys and system data from 254 participants with successfully registered SIM cards, supplemented with qualitative interviews and observations with 37 families to investigate motivations, methods, and barriers for family engagement with our literacy technology over the 4 months of the study.

In this study, we investigate:

**RQ3.1**: What are the motivations, methods, and barriers for rural families' adoption of a voice-based educational technology accessible via feature phones?

**RQ3.2**: What are the motivations, methods, and barriers for rural families' support for children's use of a voice-based literacy technology?

**RQ3.3**: How does family support for a voice-based literacy technology change over time, when deployed with rural families?

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 actively recruited older siblings and other family members to support children's system usage when the 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.

## 5.2 Methodology

### 5.2.1 Study Design

This study was intended to be a randomized controlled trial of the efficacy of Allô Alphabet in improving children's literacy outcomes. Based on power calculations from prior data on literacy assessments in rural communities in Côte d'Ivoire [104, 103], we recruited 16 schools for the control condition and 16 for the treatment condition, across 8 total villages (schools were randomized to condition within-village). 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 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.

However, prior to launching the study, a new law was passed in Côte d'Ivoire requiring all SIM cards to be registered to individuals, using government-issued photo IDs. A representative from a local telecom company accompanied us to the field sites to register participants' SIM cards during the training sessions for all 750 families. Unfortunately, we encountered significant problems successfully registering the SIM cards, including participants not having caregivers with a government-issued photo ID—problems which only became fully apparent several weeks or months into the deployment. In spite of many conversations with the telecom company, over 400 participants were not able to have their SIM cards successfully registered and could not access the IVR, thus impacting participation rates and impacting our ability to run evaluations of learning gains from the pre- to post-test with sample sizes of sufficient power.

### 5.2.2 Study 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 [120]. 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 [120, 53]. 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 often involving younger members of families from rural communities dependent on farm production [120]. 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 from which they may not recover, and, as a result, are less likely to be literate [190]. According to UNESCO, while 94% of Ivorian primary-school-aged children were enrolled in school, only 61% completed primary school [190].

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

Table 5.1: Number of participants for each data source

### 5.2.3 Data Sources

**Quantitative data: Assessments, surveys, and system data**

We administered a pretest at the start of the study to establish a literacy baseline. The pretest included items on phonological awareness in French and Attié, the primary local language, such as identifying the initial or final sounds of words (e.g., "*jour* /j/"), removing the initial or final phoneme of words and identifying the subsequent word (e.g., "*neuf* - /n/ = *oeuf*"), and items on phoneme and syllable segmentation. The test also included a basic assessment of French reading skill through grapheme identification (e.g., "what is the name of this letter or group of letters? "*ch*"), reading common words (e.g., "*mal*"), and reading invented words (e.g., "*tipa*"). Before distributing the phones, we surveyed the caregivers and participants to understand more about participants' home environment (e.g., family members' occupations, literacy, etc.), as well as children's work activities (farm labor, domestic labor, and commercial labor), adapted from the Tulane survey [230][1]. The survey and the baseline literacy assessment were based on the Early Grade Reading Assessment [99]. 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.). In addition to the baseline and endline literacy assessment data and surveys provided to children and adults, we also obtained system usage and call log data throughout the 15 weeks of the study, as participants called in to access lessons. From this source, we have data on the number of calls, duration of calls, performance on the lessons on each call - including number of questions correctly completed, number of attempts required to complete them, and more, for both the coarser-grained types of questions (e.g., identifying rhyming word pairs) and finer-grained unique questions ("does this pair of words rhyme? *Chat*, *chaud*"). See Table 5.3 for more detail on the number of participants for each type of data, given the limitations from the SIM registration issues.

**Data sources: Home observations and family interviews**

To investigate our research questions for this study 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). I conducted these interviews along with a linguistics graduate student from Côte d'Ivoire who spoke several of the local mother tongues and helped with translation. These sessions were designed to observe how families used the system at home (though there may

[1]See Chapter 6 for a longer description of these survey items, and see the Open Science Foundation pre-registration for the survey items themselves. https://osf.io/n53w8?view_only=6055dd7d46394a4c821f9e6015e1bd7c

| 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 5.2: Interview participants' relationship to child; with interview participants' occupations grouped by parentheses

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, including users who had called the IVR often and regularly; users who had called infrequently or only once; and users who had never called the IVR. 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 5.2. We took field notes and recorded and transcribed video and audio, for nearly 40 hours of data, and coded this data using thematic coding methods, as with similar data in Study 1 and 2.

## 5.3 Findings

### 5.3.1 Family literacy technology adoption

When we collected the devices at the end of the study and tested the SIM cards, we discovered that 398 of the SIM cards were never successfully registered, despite assurances to the contrary during distribution and training. We were not able to collect and test 98 (out of 750) devices, and thus, for some participants, we do not know whether they did not call because the SIM card was not registered, the device was broken or not charged, or other reasons. Thus, for this study, any data of call rates is from the group of participants who called to access the IVR at least once ($N$=236), though the interviews also included participants who never called the system, to understand reasons why they didn't call or challenges they faced.

Over the 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), or roughly once every 4.3 days, 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 over the 15 weeks ($SD$=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. 5-1 for call rates.

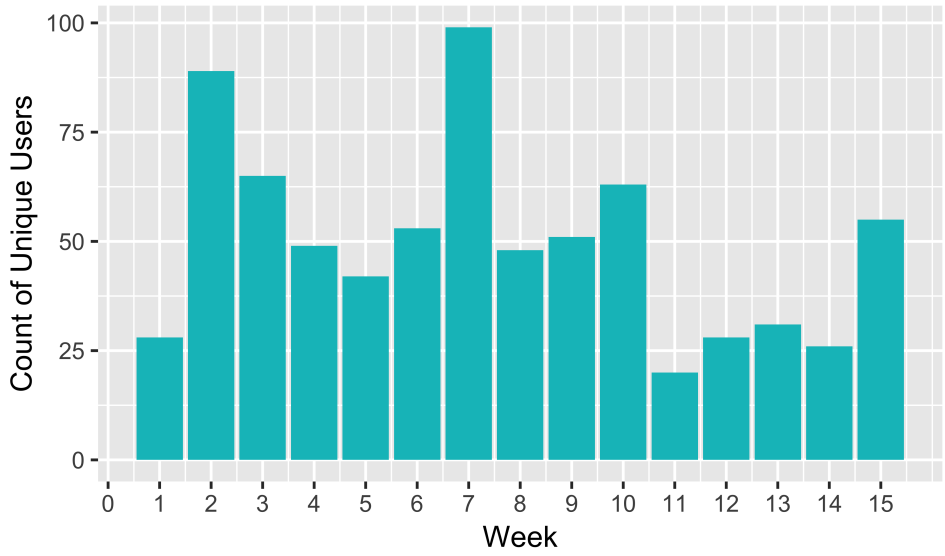


Figure 5-1: Unique users calling throughout the 15 weeks of the study

**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 in Study 1, we found that parents valued their children learning French literacy as a form of social capital [148]. In Study 3, we find further evidence that caregivers 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 the increasingly ubiquitous mobile phones in the region, saying:

> *"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 reported owning 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 [141], mirroring broader trends across Africa [140]. 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. One parent made an analogy to educational television, which was deployed in many Ivorian schools in the 1980s [254]:

> *"Previously, we talked about educational television. For people who did not know the sea, we could show them the sea. For people in the north who do not know cocoa, coffee, they will know with educational television."* (P15)

Parents also acknowledged that educational technology could be a motivating factor for children to learn, despite initial challenges in learning how to use the technology.

> *"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 caregivers kept the phones with them for safekeeping, their children's access to the system would be limited when these adults 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)

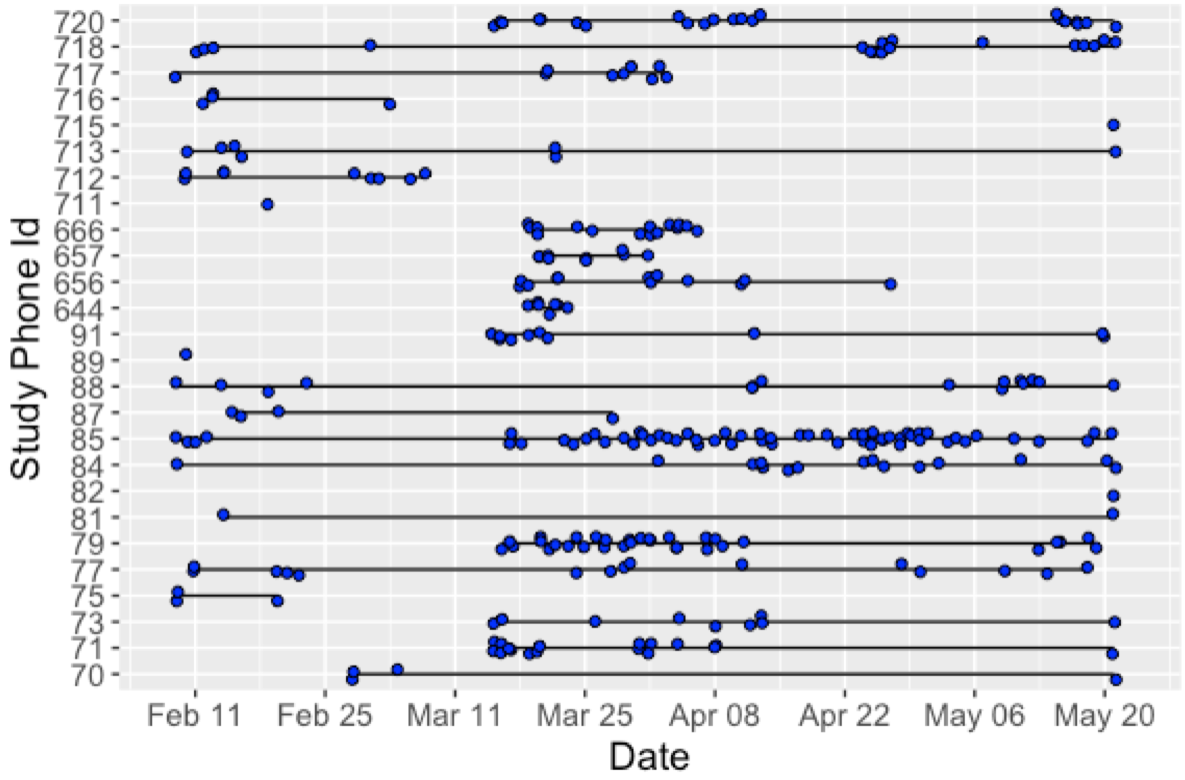


Figure 5-2: Patterns of IVR calls for one school, for 15 weeks. Each row is a user, and each dot represents a single call to the IVR for that user.

To understand these gaps in system usage, we showed participants a visualization of their individual calls throughout the 15-week study (Figure 5-2) and used this to prompt them about gaps in calling. Often, when we asked, the participants would refer to a week-long gap between calls in the visualization (see Figure 5-3) 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)

Figure 5-3: Showing the call plot visualization to a parent, asking for reflection on gaps in usage

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.

### 5.3.2 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 actively recruited networks of support from others, including older siblings, aunts and uncles, and neighbors, which we found preliminary evidence of in Study 2, in one village [145]. We found further evidence for these 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 voluntarily help children use education technology at home, and motivations for parents to actively recruit older siblings to help the child in the study use the system.

**Parents support children's learning when available**

First, we found that 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 design sessions in Study 1 [148]), 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%)). See Chapter 6 for more detail on parental occupations. Even parents 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.

**Other family members help children use education technology when parents not available**

We found that parents recruit other family members to help their children use the IVR to develop literacy to compensate for challenges from parents' availability, educational experience, and technological fluency. We found preliminary evidence for this in one village in Study 2, and here in Study 3 we identify motivations for this collective support. Because parents may not have been comfortable with children using mobile devices alone, and the parents 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)

Figure 5-4: Father and son using IVR in the father's shop

This parent described how the older brother in CM2 (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 the participant above (P11) 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. See Chapter 6 for quantitative analyses of the relationship between adult literacy and multiple forms of family educational involvement. 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 survey respondents), caregivers may not have had experience with IVR systems[2], 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 an 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 the seasonality of the cocoa harvest and by school holidays and closures. See Chapter 6 for a discussion of extended school closures due to teacher strikes during Study 3 and due to COVID-19 during Study 4. Older siblings who were still in school may have left the village to work on the farms when *their* schools were closed:

[2]In Chapter 6, we report on a survey item asking about caregivers' prior experience with automatic voice systems like the IVR.

*"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)

### 5.3.3 Children's independent educational technology use

From 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, either because no family members were available to support, or because adults believed in the importance of children learning independently. Facilitating this transition, throughout the study, we find that children began asking for more autonomy over their use of the IVR, prompting their parents or caregivers to let them use the IVR on their own.

#### Caregivers 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 Study 2 [145]. 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.

**Caregivers 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 caregivers that it was important for children to develop the ability to learn independently—specifically, to choose when they wanted to 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 explicit learning support from other family members should only be provided when children themselves 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)

While self-regulated learning can be beneficial, many children—particularly at age 8-12, as in our population—may not have the meta-cognitive abilities (or sufficiently well-developed executive functioning) to effectively regulate their own learning. 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 [8], or the social cachet of children using mobile phones.

### 5.3.4 Quantitative impact of household and child factors on IVR use

Here, I provide a quantitative supplement to our research question about the factors associated with system usage (RQ1). We first identified several potential predictor variables at the child level, adult level, and household level. Due to prior research suggesting the impact that agricultural labor has on school participation and literacy [190], we include factors related to agricultural labor participation, for both children and adults. Given prior research suggesting

| Level | Factor | Type | Source |
|---|---|---|---|
| Child | French letter reading | Scalar | Pre-test |
| Child | Phoneme awareness | Scalar | Pre-test |
| Child | Farm labor | Binary | Survey |
| Child | Domestic labor | Binary | Survey |
| Child | Commercial labor | Binary | Survey |
| Child | Family labor, other | Binary | Survey |
| Adult | Education | Categorical | Survey |
| Adult | Employment (farmer) | Binary | Survey |
| Household | Socio-economic status | Scalar | Survey |
| Household | Speaks French at home | Binary | Survey |
| Household | of phones owned | Scalar | Survey |
| Household | of siblings | Scalar | Survey |

Table 5.3: Description of variables used in children's system usage models

the importance of adult literacy and the home environment on developing children's literacy [212, 136], we include factors such as whether French is spoken at home and the caregiver's highest education level, as well as children's baseline literacy score on the pretest. Finally, we also include socio-economic measures, such as a proxy for SES based on the number of amenities owned at home [99], and the number of phones owned by the household, which may reflect families' digital literacy. See Table 5.3 for more detail.

We were interested in the impact of these factors on children's system usage, which, in this study, we operationalized as the number of calls made to the system. After removing all cases without complete testing or survey data, we were left with 136 participants in both models (from the original set of 254 participants who had ever called). No missing data were imputed. For the number of calls made to the IVR, we used a binary factor indicating whether they successfully called into the child-directed IVR interface more than once (based on the distribution of the number of calls).

To investigate the effect of each of these factors on our DV, we conducted a stepwise regression model, using an automated AIC search, where variables are added and removed one at a time to find the best-fit model [236]. We conducted a logistic regression for the probability that a child had ever called the system more than once. We find that there was a significant, negative effect of children's farm labor participation on their number of calls to the system ($-1.26$, z=-2.78, $p = 0.005$), and significant, positive effects of baseline phoneme awareness (1.42, z=1.42 $p<0.05$), domestic labor (1.51, z=2.00, $p<0.05$), and socioeconomic status (or, the count of amenities in the household) (0.21, z=2.31, $p<0.05$). In other words, children who participate in farm labor are less likely to call the system more than once, while children working at home in domestic labor are more likely. This corroborates what we heard from participants in the interviews about farm labor, but also suggests that children who work at home may have more opportunities to use the IVR. In addition, children with a higher baseline literacy and children in families with greater SES are more likely to call the system more than once, perhaps indicative of a "rich get richer" effect [132, 12]. However, given all of the technical issues with SIM card activation and the phones functioning, plus the underpowered sample (136 out of the original group of 750 who were given a phone), and the likelihood that these 136 had other factors that distinguished them from the rest of the sample, these results may not be robust. Thus, in Chapter 6, I discuss similar analyses for a more robust sample of users in Study 4.

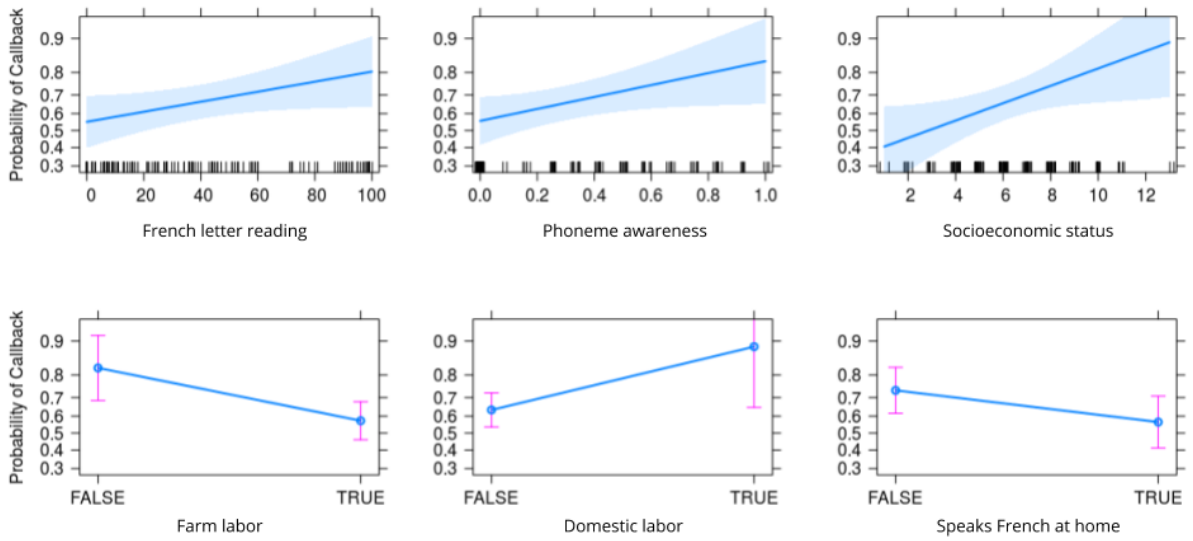


Figure 5-5: Impact of child and household factors on calling IVR

### 5.3.5 System usage during extended school closures due to teacher strikes

At the beginning of Study 3, Ivorian teachers went on strike for nearly 2 months. Although Allo 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 the learning intervention. Given that such strikes are not an isolated event in Sub-Saharan West Africa and Côte d'Ivoire [3, 254], it is thus critical to understand how families continue to use at-home educational technologies during lengthy school closures (a topic of great relevance during the 2020 COVID-19 pandemic [194]).

#### Teacher strikes in Côte d'Ivoire

There have been nationwide teacher strikes in Côte d'Ivoire since at least 1983, when teachers protested a national rollout of an expensive educational TV policy [254], which we heard an example of from a participant earlier in this chapter. This was to be a precursor of mobilization from teachers over the next 30 years. On January 22, 2019, after a series of strikes in schools in the south-central Lacs region in the previous year, COSEF, a coalition of eight teachers' unions, launched an indefinite strike in public elementary and secondary schools around the country. 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[3]. For political reasons, it is difficult to obtain an accurate estimate of the number of institutions closed during the strike. 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[4].

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

[3]https://bit.ly/2pmAjjw
[4]https://bit.ly/2VGPyQz

during the strike would be released. Schools were officially reopened on March 25th, 2019, after just over 2 months of striking. This period of closure included the first 6 weeks of our 15 week study. Thus, during the interviews, we wanted to understand how families might use an educational technology at home during the strike, and so we posed questions to parents 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 Allo Alphabet during the strike. We asked these questions of adults in 23 of the 40 families we interviewed (10 of 15 at baseline, and 16 of 25 at endline).

**Families' feelings about learning during a strike**

In our 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; (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, given that their agricultural labor often took them out of the village for days or weeks at a time, working and living at the *campement*, or farm camps.

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 – 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, father, baseline). The most common concern that parents had was that the strike would "make children late" 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 need more repetition in order to remember it (P1, father, baseline).

Parents suggested the strikes precipitated a shift from the state's responsibility for children's learning, towards families' responsibility, 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, father, endline). This parent, who also happened to be a teacher, and the president of the school-community association (COGES), believed that the state was "turning away" from the local conditions in their village. They were more conflicted about the strike than most, as they also expressed that they felt the schools needed more money to pay the teachers fairly. Another family adult also acknowledged that there was an underlying problem motivating the strike, saying, "it must be said that there is never smoke without fire. It is because there is a problem that teachers here are on strike." (P34, older brother, baseline). Other parents were not quite as understanding, with one saying directly, "the teachers must not continue to strike." (P22, mother, baseline), while other parents put the responsibility on the state to end the strike, saying, "The state, the president and the ministry of education must quickly resolve the problem when there is something wrong"(P1, father, baseline). Another adult explicitly described this shift in responsibility for education from the state to the individual, saying "it is now up to the parents to be vigilant so children don't abandon their studies" (P34, older brother, baseline).

Parents felt their children should continue learning during the strike. Some parents told us how they hoped our system would allow their child to continue doing exercises even when the parents were not home. Before the study started, parents told us how "If there is a strike, even on vacations, you must always read and learn something." (P29, father, baseline). Another family member told us how Allo 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, aunt, baseline). Others told us that they would tell their child to use Allo Alphabet "If you have some time to call during the day" (P28, grandfather, baseline) 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, mother, endline)

However, parents felt unable to enforce their children's learning during the strike, due to their travel out to the fields, to other villages, or from their other work responsibilities. Parents told us that, before the strike, the older siblings who are still in school would help the child, but "once the strike started, the older brothers have gone to the *camp*." (P11, mother, baseline). 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 *camp*". (P11) Other parents told us how, during strikes, they feel that their children who are still of school age need to remain back 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, father, endline). 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, mother, baseline)

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, mother, baseline). Although this autonomy on the part of the child did not always result in the child studying, as , 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, father, endline)

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 the phone 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 Allo Alphabet]. I was surprised that she came to ask me for it." (P34, older brother, endline) 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.

### Children's ed tech usage during the strike

Thus, because parents often did not know whether their children used Allo Alphabet during the strike, we used the system log data to identify whether and how children in our study actually *did* continue learning during the teacher strike. We used log data from the usage of

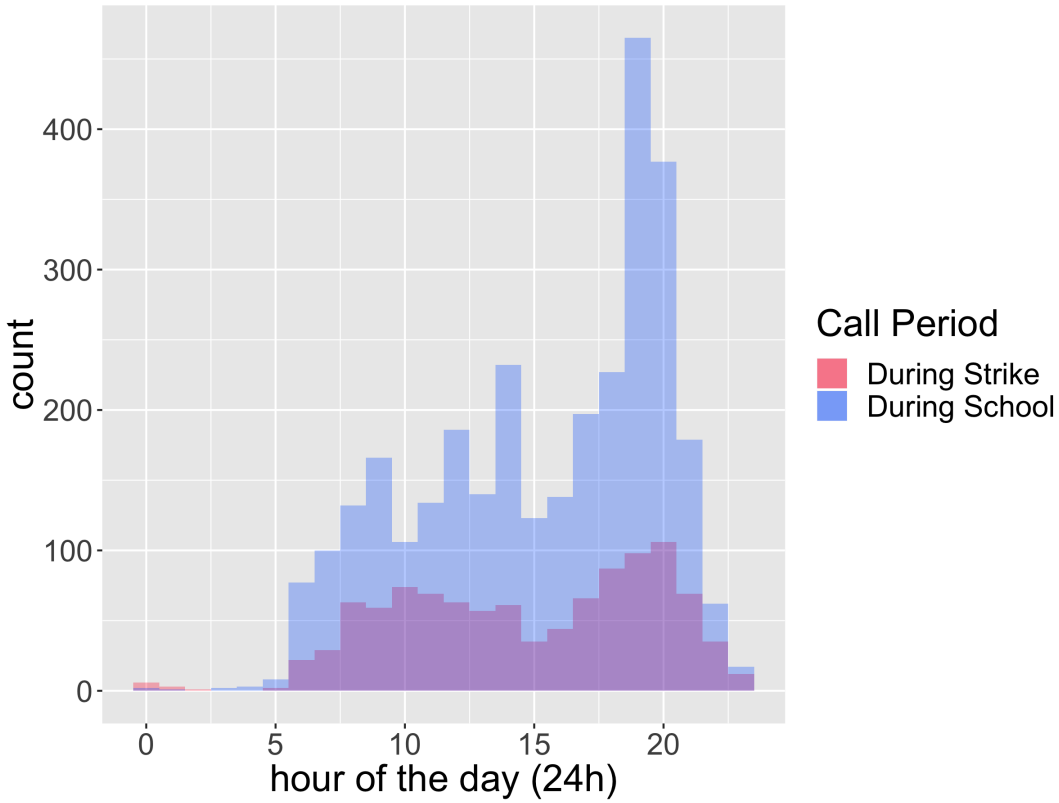


Figure 5-6: IVR call times during strike and school periods

Allo Alphabet to understand how children's use of our system differed in the 6 weeks of the teacher strike compared with the other 9 weeks of the study when school was in session. All p-values remain significant after controlling for multiple comparisons with a post-hoc Bonferroni correction.

First, we investigate whether there were differences in the amount that children accessed Allo Alphabet, by calling in to the interactive voice response (IVR) platform. We find that there was no significant difference in the number of students calling in per week during the strike (54) compared with the school period (47), t(14.12)=0.51, p=0.62. There was also no significant difference in the average number of calls students made per week to the IVR during the strike ($M$=3.38 calls, $SD$=6.0,$Med$=2) compared with the school period (4.3,$SD$=5.2,$Med$=2), t(195.3)=-1.41, p=0.16. 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. However, during the strike, students called the IVR at more evenly distributed times throughout the day, with a median call time of 3:00pm ($SD$=4.87 hours), compared with 5:00pm during the school period ($SD$=4.5 hours), (t(19901)=-9.02, p<0.001). See Figure 5-6 for the distribution of calls throughout the day.

Then, to investigate differences in the literacy lessons completed by students, we analyzed differences in 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 Allo Alphabet during the strike ($M$=121.5 seconds, $SD$=376.91s) compared to during the school period ($M$=95.6s, $SD$=264.5s), (t(7945)=5.67, p<0.001). In addi-

tion, perhaps as a result of that greater amount of time spent using the system, during the strike, students completed more questions on average ($M$=55.9, $SD$=42.2, $Med$=50) than during the normal school period ($M$=50.6, $SD$=37.8, $Med$=35), t(4883)=6.15,p<0.001. However, there was no significant difference in the average correctness of these questions (t(5321)=0.68,p=0.49).

## 5.4 Discussion

After designing and developing a voice-based literacy curriculum for low-cost mobile devices in Study 1 (Chapter 3) and Study 2 (Chapter 4) [148, 145], we deployed Allô Alphabet with families in 8 rural communities in Côte d'Ivoire for 15 weeks. In this chapter, we identify how and why children and their families used Allô Alphabet, drawing on data from interviews with 37 families throughout the study. 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.

### 5.4.1 Digital literacy skill acquisition

As mobile devices have become increasingly ubiquitous in communities around the world [141, 140], educational technologies are increasingly being developed and deployed on these devices, including smartphones [127] and messaging services for smartphones and feature phones [186]. 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 (i.e., due to adults' concerns) for the adoption and use of educational technology. Our data suggests that caregivers drive technology adoption (e.g., as "enablers" [110]) via their belief that digital literacy is a critical component of children's education, and part of caregivers' aspirations for their families' future (cf. [129]).

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 design sessions with families in Study 1, caregivers expressed similar concerns about children's use of mobile devices [148]. 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 [91, 86]. 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. [91]).

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 the context. 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 at first, although family members provided multiple forms of explicit and implict support to model and teach children how to use the IVR. 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 from others in the family or community 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 (much like we saw in Study 2 [145]), in ways that may not have been possible with less ubiquitous technologies (e.g., smartphones [127] or tablets [229], 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") [41, 124]. However, designers of educational systems often model the content knowledge—here, French literacy or phonology skills. Future work may thus explore whether or how it might be possible to develop models of digital literacy skill acquisition (e.g., using Bayesian Knowledge Tracing [257], perhaps using system data or assessments) and suggest support from 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., [191, 192, 193, 177, 164, 150]), our findings suggest that, if such systems are to be designed for children, they should be designed to explicitly scaffold technological fluency for IVR.

### 5.4.2 Limitations and future work

Given all of the issues with SIM registration, we did not have sufficient power to conduct statistically significant analyses of learning gains. To address this, for Study 4, we obtained permission from the Ivorian Ministry of Telecommunications (ARTCI) to register all 750 SIM cards with a representative of the national organization of parent-school partnerships (COGES) to circumvent this problem. In addition, although we used survey items to investigate whether children had support from an adult, we did not ask about the nature of that support. Thus, in Study 4, we included a survey item asking 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. These issues of SIM registration and family support for learning at home during school closures are not simply outlier phenomena, but are fundamental aspects of learning technology research, design and deployment that are often bracketed out of the research focus and goals. See Chapter 7 for a larger discussion of the political dimensions of educational technology research.

### 5.4.3 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 understanding how children and their families in agricultural communities might use a literacy technology at home over an extended duration. In this study, we conducted semi-structured interviews with 37 families of a larger set of 256 users of Allô Alphabet to investigate motivations, methods, and barriers for rural families' adoption, use, and support for our literacy technology, and how that family engagement changed over time, supplementing this with quantitative analyses of system usage and children's baseline literacy and labor activities, as well as analyses of their system usage during an extended period of school closure during a teacher strike.

We find that families view digital literacy as a distinct learning goal, they leverage networks

of supporters to compensate for gaps in parents' availability and literacy (both digital and French), and over time, they transition that support from more explicit to more implicit support for children's independent learning, as they perceive children are able—and want—to learn more independently. 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. In the next chapter, I discuss how we designed new elements of the Allô Alphabet system, based on the findings in Studies 2 and 3, and I discuss results from Study 4, using quantitative analyses of survey data to understand the impact that the factors described in this chapter and the preceding have on families' adoption and children's use of Allô Alphabet.

# Chapter 6

# Individual and Family Factors in the Use of Allô Alphabet (Study 4)

## 6.1 Introduction

After the longitudinal deployment of Allô Alphabet in Study 3, we decided to conduct another randomized controlled trial to evaluate the impact of Allô Alphabet on children's literacy learning gains. After the challenges we faced with registration of SIM cards to caregivers in Study 3, we obtained a waiver from the Ivorian Ministry of Digital Economy to allow us to register all the SIM cards to a representative from the Ivorian COGES (*Le Comité de Gestion des Etablissements Scolaires*). Armed with this, and with support from Jacobs Foundation, we felt confident in launching another longitudinal randomized controlled trial (RCT) to evaluate the effectiveness of Allô Alphabet. This study launched in December 2019, with 777 children in the CM1 grade (5th grade equivalent) in 16 schools in 8 villages in the rural eastern region of Côte d'Ivoire, and is ongoing at the time of writing in May, 2020. We had planned to conduct a literacy post-assessment in spring 2020 to evaluate learning gains between a pre- to a post-test after using Allô Alphabet. Unfortunately, due to COVID-19, schools in Côte d'Ivoire, like much of the rest of the world [16] were closed, and thus our research team was unable to return to the field sites to conduct our endline assessment this spring. However, given our qualitative data about families' support and system usage in Studies 2 and 3, in this chapter, we investigated how the family support structures and home language and literacy contexts (among other aspects of the families) impacted children's use of, and progress through, the Allô Alphabet literacy platform. We thus use the data that we have available, from a literacy pre-assessment, surveys of children and a caregiver, and system usage data, to investigate the following questions:

**RQ4.1**: How are child-level and household-level factors (e.g., language and literacy, SES, work activities, family support, etc) associated with rural Ivorian primary school children's likelihood to (a) call and (b) complete questions on Allô Alphabet?

**RQ4.2**: How are child-level and household-level factors (e.g., language and literacy, SES, work activities, family support, etc) associated with rural Ivorian primary school children's likelihood to master various types of skills in the Allô Alphabet curriculum?

**RQ4.3**: How does adults' use of a version of Allô Alphabet designed for adult supporters impact children's likelihood to (a) call, (b) complete questions, and (c) master skills in the Allô Alphabet curriculum?

Following these, in an addendum, I discuss findings from a series of individual calls made with members of 728 families to understand how the closures of schools due to COVID-19

impacted their use of Allô Alphabet.

We find that, in our study of 777 children using Allô Alphabet for 21 weeks, that children in families with greater educational involvement from family members were more likely to attempt more questions in the Allô Alphabet curriculum, and children who had someone access the adult supporter version of the IVR system were more likely to call, attempt questions, and master the curriculum, but only for certain menu options in the adult supporter system (e.g., personalized information about children's progress and instructions for literacy games to play with the children), suggesting benefits of certain types of scaffolds for adult support. In addition, we find that children from families with lower socio-economic status (SES) and parental education were more likely to call the IVR and attempt more questions, while children with higher baseline literacy were more likely to call and master skills in the curriculum. Finally, we find that children's participation in work activities is significantly associated with calling and attempting questions in the system, but the specific work activities they engage in have different associations, with a positive association between children doing hazardous cocoa tasks and their number of calls to the IVR, and a negative association between doing non-hazardous cocoa tasks and commercial activities and their calls and questions completed. Through these findings, this chapter provides a quantitative complement to findings from studies 1-3 (Chapters 3, 4, and 5). In the discussion at the end of this chapter, in Section 6.5, I discuss some of the findings, and in the final chapter of this dissertation, Chapter 7, I make connections between findings across all 4 studies, and discuss their implications and contributions in light of prior work.

## 6.2 Methodology

### 6.2.1 Allô Alphabet System Revisions

Following our design-based research methodology, we have iterated on the design of the Allô Alphabet system following design implications from system prototypes tested with children in Study 1 and from previous deployments of this system in Study 2 and 3.

#### Motivational elements

In Study 2 and 3, we found that children may not call in at the frequency and regularity which may be necessary for the system to be most effective in supporting their literacy. Drawing on findings from our observations and interviews with families, we identified a set of design opportunities for motivating students to continue to call in to the system more frequently. Based on prior work that suggests that including games into an educational curriculum that are progressively unlocked as children advance may be motivational [174, 106], we designed motivational content such as word games and drawing games which could be provided via voice instructions unlocked at intervals throughout the curriculum. These were designed for children to hear the instructions on the call, but to be played after the call, because of the difficulty in hearing instructions from a phone while playing games. We developed and piloted some of these offline word games during the observation sessions in Study 1 and 2.

In Study 1 and 2, we prototyped several literacy game options with children that they could play with each other without needing to be on the call with the IVR system. We tested several types of games and iterated a set of methods for teaching these games to children, from having the researcher explain the instructions verbally (Study 1), to having the IVR system provide these instructions to children or having the IVR system provide the instructions to the parents,

who taught the game to their children (Study 2). In these prototyping sessions, we experimented with games involving 1) children choosing a letter or syllable and listing as many words that began or ended with that letter or syllable as possible; and 2) drawing games where one child drew an object that began with a designated letter or syllable, and the other children needed to attempt to guess the word drawn and write down the initial letter of the word, gaining a point if they were the first child to do so, among other games. When prototyping these games, the children were so interested in playing that they often asked us to continue playing after the session, and many remained behind to continue playing after the researchers ended the session.

**Adult Literacy Supporter System**

In addition, evidence from prior work and our own prior studies (Study 2 and 3) suggests that family members may benefit from additional scaffolding for the support they provide for children's literacy. We thus designed a portion of the literacy system which provides such scaffolds to adult supporters via interactive voice response (IVR), in a similar way to the child-facing version of Allô Alphabet. The design goals were to 1) provide information about the purpose of the study, the IVR system, and the importance of regular practice for fostering early literacy skills; 2) provide scaffolds for motivational and socio-emotional support using data on the children's recent system usage and learning performance; and 3) provide scaffolds for instrumental support on the learning process, from telling adults about the types of concepts and questions children are most struggling with and providing suggestions for help, to providing more generic suggestions for involvement in children's literacy development.

First, we (1) created a feature in the adult supporter system to provide parents and other adult supporters with information about the value of phonology for literacy, the importance of regular practice for literacy development, and information on how their children can use the system. Because some families participating in Study 2 reported not knowing why their child was answering rhyming questions instead of learning to read, as well as other issues we saw with families not knowing how their children were expected to respond in the system, this seemed crucial to the successful uptake of the early literacy system, given the significant role parents and other adults in the family play in communicating values about the importance of literacy to their children [46, 133]. In Study 1, we saw parents telling us of the importance of literacy to advance their families, but without the connection between the distal goal of literacy and the immediate gains that children are making on phonemic awareness in the system, adults may not communicate these values to their children. In addition, because several of the families in our study had no adults who spoke sufficient French to understand the calls, we recorded versions of these informational messages in some common local languages for this region (i.e., Attié, Kulango, Dioula, and Bété).

Second, we (2) have designed scaffolds for adults to provide motivational and socio-emotional support to their children. While parents in Study 1 told us that they often provided encouragement to their children in their education, and we observed some adults in Study 2 and 3 giving such encouragement during the lessons we observed, it is not clear that this encouragement was provided to children when it might be of most value, nor targeted at the most effective aspect of learning (i.e., the part of the curriculum or "skill" the child is having the most difficulty with). More generally, Landry and Pianta [133, 183] discuss how parents may provide a "secure base" from which children may feel comfortable taking risks in learning content which may be challenging or difficult. But parents or other family adults may not have the self-efficacy for literacy *themselves* to provide such motivational and socio-emotional supports [97, 76]. Further, even adults with such self-efficacy may not know when or how to motivate their children. Therefore,

as one instantiation of this type of scaffold, we have designed messages to inform adults about, first, children's patterns of system usage—either consistent streaks of calls or gaps in children calling in—and reminding adults to encourage their child to continue calling in if they have lapsed. This follows from prior work [256, 126], which found evidence that brief nudges from parents were successful in promoting pro-literacy behaviors from their children.

Finally, our third high-level design goal for scaffolding adult support is for (3) supporting parents' instrumental help with the system and content itself. As we observed in Study 2 and 3, many adults are already spontaneously providing assistance and advice to children during the lesson, without prompting or scaffolding from us. However, these adults may be those who are already literate, thus leading to a potential "rich get richer" effect [132, 12]. Further, as we observed in Study 2 and 3, even adults with sufficient literacy to write out letters and words on their chalkboards may not know the specific concepts or questions their children are struggling with to offer help that will be targeted where it is most needed. Family literacy supporters in Study 2 and 3 told us repeatedly that they wanted to know more about what types of lessons children were receiving, since they often couldn't hear the questions on the call, or weren't present during the lesson. Given that even many of the adults in Study 2 and 3 who *were* helping their children with the content didn't know which types of questions their children were struggling the most with, we provided family literacy supporters who access the adult supporter system with summaries of the concepts that child is currently learning. We also provided them with personalized information about the specific types of questions their child is currently struggling with (based on that child's performance data on that question type), with hints and examples to help the adults help their children. These designs were instantiated into an IVR call flow for adult supporters (see Figure 6-2 for an excerpt of the main menu options for the adult supporter system, and see Appendix A for the full system diagram) and written into messages recorded by an Ivorian speaker.

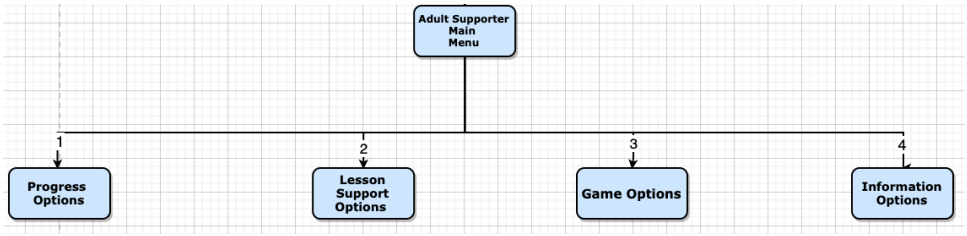


Figure 6-1: Call flow diagram of the adult supporter IVR system - main menu options

### 6.2.2 Study Design

Much like Study 3, this study was intended to be a randomized controlled trial of the efficacy of Allô Alphabet in improving children's literacy outcomes. Based on power calculations from prior data on literacy assessments in rural communities in Côte d'Ivoire [104, 103], we recruited 16 schools for the control condition and 16 for the treatment condition, across 8 total villages (schools were randomized to the two conditions within each village). The villages were the same 8 villages as in Study 3, with schools randomly re-assigned to the treatment and control conditions. Prior to analysis of any data, we pre-registered our study design, analyses, and hypotheses with the Open Science Foundation, which can be found here[1]. However, due to school closures in response to COVID-19, we have not yet collected the endline data described

[1]https://osf.io/n53w8?view_only=6055dd7d46394a4c821f9e6015e1bd7c

in the pre-registration. This is planned for October 2020, after the schools re-open. In each of the 16 schools, we recruited students from the CM1 class, for a total of 777 children in the treatment condition ($M$=48.6 students per class) and 426 children in the control condition ($M$=26.6 students per class). The average age of the participants across both conditions was 10.8 years old ($SD$=1.5, $min$=6, $max$=17). 50% were boys and 48% girls (2% did not respond).

Figure 6-2: Image of a training session with caregivers and children

At the start of the study, we provided a one-hour training for children in the treatment condition and at least one caregiver, in which we explained the purpose of the study, distributed the phones (with the SIM cards already registered to the COGES representative) and explained how to place calls and access SMS messages, and taught them to use the Allô Alphabet IVR. See Figure **??** for an image of the training. During this training, we also provided a survey to the caregivers, asking questions about their relationship to the child, their education and occupation, and more. Similar to Study 3, we provided all participants in both treatment and control conditions with a pre-assessment, based on the internationally validated Francophone EGRA assessment [99], including survey items provided to the children on their family's language and literacy environment, caregivers' occupations, and various household amenities (as a proxy for socio-economic status). See the next section for more detail on the survey items and see the Open Science Foundation pre-reigstration for the full survey [2].

### 6.2.3 Identifying technical issues

Given the issues experienced in Study 3, we wanted to ensure that all of the participants whose data would be used in the models had a working device. Thus, in February, 2020, (after 10 weeks of the study) several members of the Eneza Education technical team visited each of

[2]https://osf.io/n53w8?view_only=6055dd7d46394a4c821f9e6015e1bd7c

| Construct | Description | Respondent | Source | Total Respondents |
|---|---|---|---|---|
| 1 (IV) | Baseline literacy | Child | EGRA assessment | 1125 |
| 2 (IV) | Baseline language | Child | EGRA assessment | 803 |
| 3 (IV) | Family language and literacy | Child | Survey | 1203 |
| 4 (IV) | Socio-economic status | Adult and child | Survey | 720 |
| 5 (IV) | Work activities | Child | Survey | 1152 |
| 6 (IV) | Family educational involvement | Adult | Survey | 687 |
| 7 (IV) | Family technology | Adult | Survey | 491 |
| 8 (DV) | System usage | Child | System log data | 536 |
| 9 (DV) | Curriculum progression | Child | System log data | 429 |
| 10 (DV/IV) | Adult supporter system usage | Adult | System log data | 382 |

Table 6.1: Description of data sources

the 8 villages to set up a tech support station at the local schools, where children could bring their phones if they had technical problems. We had heard anecdotally that some participants were having troubles (even after the successful registration of all 777 SIM cards to the COGES representative) and thus our technical team wanted to be available to help resolve these if possible. Then, several members of our Ivorian research team called each of the participants in May, 2020, (after 21 weeks of the study) to ask about their experience using Allô Alphabet and identify if they had any technical issues.

Of the 777 participants in the treatment group, our Ivorian research team called 728 (94%) with a phone number that a caregiver provided us during the training and phone distribution. Of these, 196 (27%) did not respond or could not be reached due to a lack of network access in the farms. 44 (6%) had phones that were lost, stolen, or damaged beyond repair. These 44 were thus removed from the dataset. Between the in-person troubleshooting conducted by the Eneza team and the self-reports on these calls, 148 reported some type of technical issue that prevented them from calling (e.g., the Allo Alphabet number was unintentionally blacklisted, the SIM card PIN number was locked, and others). One option would be to remove these 148 users from the dataset, but the Eneza team was able to resolve many of the issues in-person, and, of the 148 with issues, 98 (66%) had placed at least one call to the IVR, and thus we would not be able to ascertain whether the lack of call was due to the technical issue, or to other factors responsible for non-participation. I thus left these in the dataset, and created a binary variable ("any_issues") for whether they had experienced issues, which I included in the usage models (RQ1). In addition, I will discuss other challenges faced by families reported in these calls in the addendum in Section 6.4.6.

## 6.3 Findings: Descriptive Statistics

In this section, I will discuss the 10 constructs used for data analyses in Study 4, including descriptive statistics for each. The first 7 constructs will be used as independent variables, and constructs 8-10 will be used as dependent variables in the analyses in Section 6.4. See Table 5.3 for an overview of the data sources.

**Independent Variables (IVs)**

### 6.3.1 Construct 1: Children's baseline literacy (IV)

Children's literacy is operationalized as performance on three emergent literacy skills adapted from the French version of the Early Grade Reading Assessment (EGRA) [99]. First, knowledge of letters and groups of letters is a measure of emergent knowledge of symbol to sound mapping, operationalized as the number of graphemes and grapheme clusters identified (out of 100) in 60 seconds. Second is familiar words, a measure of identification and decoding of French words, operationalized by the number of French words read (out of 50 words) in 60 seconds. The third literacy skill is pseudowords, which is a measure of emergent skills in decoding invented words that conform to French phonotactic rules, operationalized by the number of French-like pseudowords read (out of 50) in 60 seconds. The mean score on the grapheme identification tasks was 21.8 (out of 100), $SD$=18.4, $Med$=15, $min$=0, $max$=96. The mean score on the word identification and decoding was 9.7 (out of 50), $SD$=13, $Med$=5, $min$=0, $max$=50. The mean score on the pseudo-word reading was 6.7 (out of 50), $SD$=10.6, $Med$=2, $min$=0, $max$=50. These three items are summarized using a summary index described in more detail in Section 6.4.1.

### 6.3.2 Construct 2: Children's baseline language (IV)

Children's language ability is operationalized as performance on three items adapted from the French version of the EGRA for phonological awareness (PA), vocabulary, and oral comprehension. First, phonological awareness is evaluated through several measures: (1) initial sound suppression, where children repeat a word without the first phoneme (initial sound), (e.g., "pomme" becomes "om"); (2) initial sound identification, where children identify which words begin with the same sound; (3) final sound suppression, where children repeat a word without the final sound; (4) final sound identification, where children identify which words end with the same sound; and (5) segmentation, where children say all of the sounds that make up a word in order, individually. Then, we evaluate children's vocabulary knowledge, in which children hear a word and identify a word with the same or the opposite meaning, and, finally, oral comprehension, where children listen to a short story and respond to comprehension questions related to the story. The mean score on the phonological awareness tasks was 15.3 (out of 40), $SD$=10, $Med$=14, $min$=0, $max$=40. The mean score on the vocabulary tasks was 3.2 (out of 20), $SD$=3.4, $Med$=2, $min$=0, $max$=18. The mean score on the oral comprehension tasks was 3.1 (out of 5), $SD$=1.4, $Med$=3, $min$=0, $max$=5. These three items are summarized using a summary index described in more detail in Section 6.4.1.

### 6.3.3 Construct 3: Family language and literacy (IV)

The family language and literacy background is operationalized by a set of survey items for children self-reporting on (1) a binary measure of whether the child reported that French was spoken at home (in a multiple response questionnaire); (2) the number of adults in the family who speak French, (3) the number of adults in the family who read, and (4) a binary measure of whether the family has books at home. These four items are summarized using a summary index.

Across the 777 participants in the treatment group, 219 (28.2%) children reported speaking French at home, in the multiple-response question asking about languages spoken at home. 51% reported speaking Attié at home, and the rest reported speaking Koulango, Dioula, Bété,

| Item | Count (and percent) of respondents |
|---|---|
| Telephone (mobile or landline) | 715 (92%) |
| Electricity | 687 (87%) |
| Television | 461 (59%) |
| Running water | 425 (55%) |
| Bicycle | 397 (51%) |
| Motorcycle | 371 (48%) |
| Radio | 370 (48%) |
| Children's toy | 309 (40%) |
| Indoor bathroom | 224 (29%) |
| Refrigerator | 222 (29%) |
| Car, tractor, 4x4 | 77 (10%) |
| Boat or canoe | 72 (9%) |
| Internet or wifi | 54 (7%) |

Table 6.2: List of household amenities, and the count and share of respondents who reported having that amenity in the household

Baoulé, or one of 18 other unique languages reported. Children report, on average, 2.1 people in their family who could speak French ($Med$=1, $SD$=2.67). Nearly all children (717/777, or 92.3%) reported having someone in their family who could read. On average, children reported that 3.3 members of their family could read, not including themselves. A majority of children (456/777, or 58.7%) reported having at least one book (*livre de lecture*) at home, but only a third (257/777, or 33.1%) reported having a book for children (*livre pour enfant*) at home.

### 6.3.4 Construct 4: Household socio-economic status, education, occupation (IV)

The family's socio-economic status is operationalized by a set of survey items comprising (1) a 15-item questionnaire given to children of binary measures of amenities found in their home (e.g., electricity, running water, refrigerator, television, etc), as in the Early Grade Reading Assessment Toolkit (EGRA) [99], (2) an ordinal measure of parental education (e.g., none, primary, secondary, tertiary, coded as 0, 1, 2, or 3) as self-reported by parents in a survey, as well as (3) a binary measure of the parents' self-reported occupation (i.e., whether they are a farmer or not). These three items are summarized using a summary index.

For the 15-item survey of household amenities indicative of socio-economic status (SES), the mean response total was 6.5 items (out of 15) ($Med$=7, $SD$=2.77). The most common items were a telephone, electricity, a television, and tap water from a pump. The least common items were a car, truck, or tractor, a boat or canoe, and Internet or wifi. See Table 6.2 for more detail.

The most common highest education level reported by parents was primary education (30% of fathers and 35% of mothers), with a plurality of respondents reporting that fathers had completed secondary education or higher (35%), and a plurality of respondents reporting that mothers had not completed any formal education (44%).

The majority of respondents reported that fathers primarily worked as cocoa farmers (435/777, 56%), and the majority of mothers reported working as *artisanat*, which is interpreted by respondents and other cultural informants to mean a maker and seller of small goods (including vegetables, spices, and other consumables) (403/777, 51.9%), with others reporting working as a salesperson more generally (125/777, 16%) or cocoa farmer (87/777, 11%).

### 6.3.5 Construct 5: Children's work activities (IV)

Children's work activities is operationalized using a one-on-one questionnaire with children comprising 4 sets of questions about (1) total number of non-hazardous agricultural activities, (2) total number of hazardous agricultural activities, and (3) total number of domestic work activities, and (4) total number of other economic work activities (e.g., selling at the market, working on a construction site, etc.).

The agricultural items were drawn from the Tulane Surveys of Child Cocoa Labor in West Africa, conducted in 2008/09 and 2013/14 [230]. Children are asked to self-report on whether they engage in specific agricultural activities common on cocoa plantations, including land preparation activities (land clearing, felling and chopping, burning, stumping, cutting stakes), planting activities (planting suckers, preparing and planting seedlings, sowing at stake), farm maintenance activities (weeding, spraying insecticides, applying fertilizers, fungicides, herbicides or other chemical, carrying water for spraying, doing sanitation and pruning, doing mistletoe control), harvest activities (plucking cocoa pods, gathering and heaping cocoa pods, breaking cocoa pods and fermentation), and post-harvest activities (carting fermented cocoa beans, drying cocoa beans, carting dry cocoa beans to shed). These agricultural items are categorized as either hazardous or non-hazardous (by [230]). These 4 groups of items (hazardous and non-hazardous agricultural, domestic, and commercial) are summarized using a summary index.

For commercial work (e.g., selling goods in the market), the mean number of activities done by each child was 4.1 ($min$=0, $max$=9, $SD$=1.8). The mean number of domestic work activities (e.g., take care of younger children, help with cooking, etc) was 4.8 ($min$=0, $max$=7, $SD$=1.18). Finally, for agricultural work (both hazardous and non-hazardous), the mean number of activities done by each child was 10.5 ($min$=0, $max$=24, $SD$=5.9, $Med$=11). We hypothesized that these responses may have been significantly related to the gender of the child, based on prior research in the context [201], and thus ran 4 ANOVAs for the relationship between gender and agricultural (hazardous and non-hazardous), commercial, and domestic activities. There was a significant relationship between gender and the number of hazardous ($F(1,597)=70.1$, $p<0.001$) and non-hazardous ($F(1,597)=88.8$, $p<0.001$) agricultural activities, with boys doing more hazardous agricultural activities ($M$=1.4) than girls ($M$=0.5), and more non-hazardous agricultural activities ($M$=6.7) than girls ($M$=3.2). There was also a significant relationship between gender and commercial activities ($F(1,1166)=35.2$, $p<0.001$), with boys doing more commercial activities ($M$=4.5) than girls ($M$=3.8). We did not find a significant effect of gender on the number of domestic activities. See Figure 6-3 for the distribution of agricultural activities (both hazardous and non-hazardous) by gender.

### 6.3.6 Construct 6: Family educational involvement (IV)

The caregivers who went to the phone training and information session were asked whether they felt they were the "principle person responsible for the education" of the child. While this question was intended to obtain the contact information of an adult we could follow-up with for future contact with the participants, this question also gave us insight into how respondents perceived their role in the child's education. The majority of the caregivers at the training responded that they were responsible for the child's education (506/777, 65%). To further investigate our questions around the nature of the support that children are provided by other members of the family, we asked about their relationship to the child. As you can see in Figure 6-4, the caregiver at the training were various members of the children's family, or, in some cases, their home tutor, teacher, or neighbor. Further, the respondents were largely mixed in


Figure 6-3: Number of agricultural activities (hazardous and non-hazardous) done by respondents, by gender

whether they felt responsible for the education of the child.

Then, we provided the caregivers with a 11-item questionnaire about the nature of their involvement, asking about whether they pay for school supplies or a home tutor, whether they communicate with teachers or attend school meetings, whether they talk with the child about school, remind them or help them with their homework, read to the child, give advice about education, teaches domestic tasks, or disciplines the child. Across these 11 binary items, the mean score was 8.4 ($Med$=9, $min$=0, $max$=11, $SD$=2.33). See Figure 6-5 for these scores broken down by relation to the child.

The most common responses were paying for school supplies, teaching domestic or life tasks, and offering advice about education. The least common responses were reading to the child, calling or texting the teacher, and paying for a home tutor. See Table 6.3 for more details on the responses.

### 6.3.7 Construct 7: Household mobile phones and IVR (IV)

Household technology ownership and experience is operationalized by caregivers' responses to three survey items on (1) the total number of basic phones owned in the household, (2) the total number of feature phones owned in the household, and (3) a binary item on whether the caregiver responding to the survey had previous experience using an interactive voice response system similar to Allô Alphabet. These three items are summarized by a summary index.

Caregivers reported that on average, the child's household (*ménage*) owned 3.4 phones ($min$=0, $max$=15, $Med$=3, $SD$=2.3), with an average of 2.2 basic, feature phones per household ($Med$=2, $SD$=1.6) and an average of 1.3 smart phones per household ($Med$=1, $SD$=1.5). When we asked the respondent if they had had prior experience with an interactive voice response (IVR) system, the plurality (344/777, 44%) had not, and nearly a fifth of caregivers (152, 19.6%) had used an IVR before Allô Alphabet.

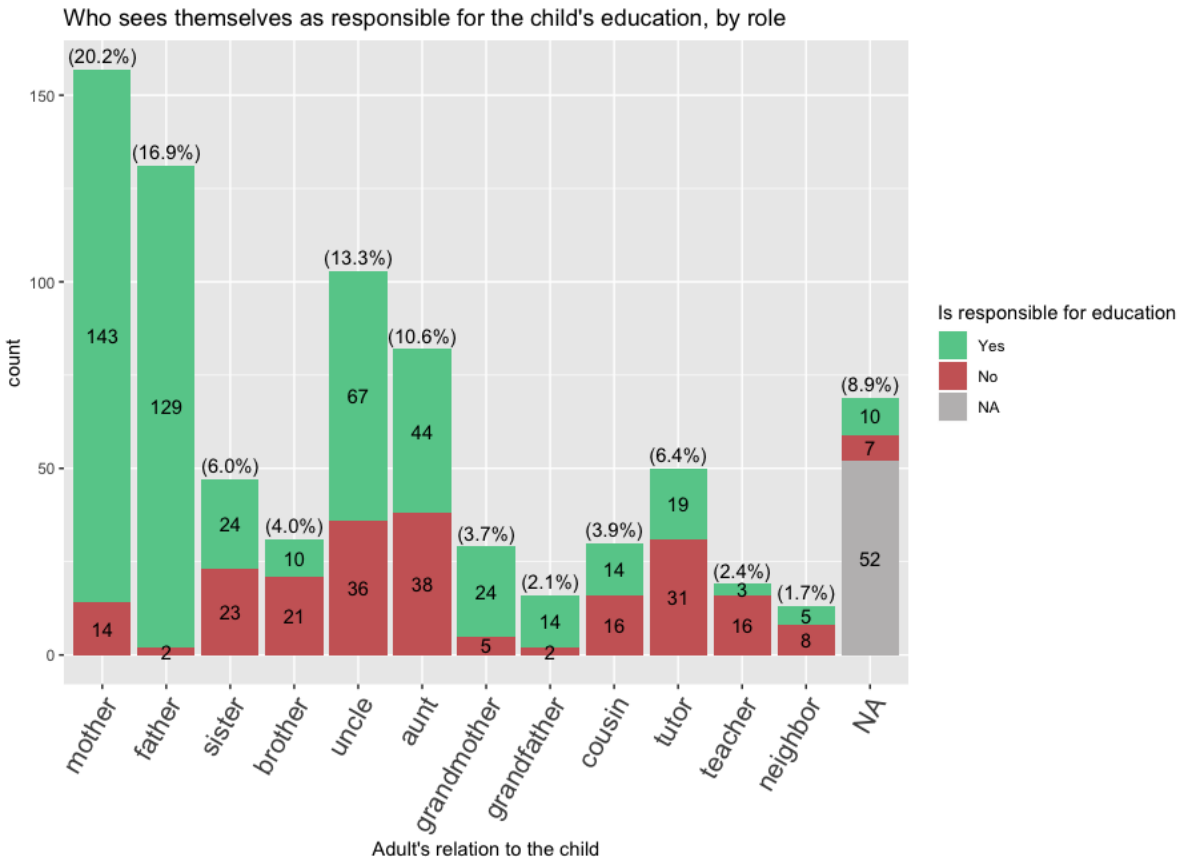


Figure 6-4: The caregivers at the training, their relation to the child, and whether they felt they were the one responsible for the child's education

**Dependent Variables (DVs)**

### 6.3.8 Construct 8: Children's system usage (DV)

Children's system usage is operationalized as (1) a scalar value of the number of times a user successfully called the system; and (2) the number of unique questions in the curriculum that a child attempted throughout the duration of the study. The measure of a successful call is logged in the database when a user dials the Allô Alphabet IVR number, receives the callback from the IVR, and answers that callback. The number of questions attempted is incremented in the database when a child responds (i.e., pushes a touchtone button) to an answer prompt for a unique question. This measure is the total number of unique questions attempted by each child. We do not combine these two measures into a summary index, as they are measuring two distinct behaviors—calling the system and attempting questions. We will use these as two separate dependent variables in the RQ1 analyses of system usage.

For our first usage measure (1), 622/777 (80%) of children placed a successful call to Allo Alphabet. The mean number of calls was 67.5 ($SD$=90.7, $Med$=28, $min$=0, $max$=651) throughout the 21 weeks of the study. See Figure 6-6 for the calls per week (Note: the IVR server was down during week 10 due to an outage). On average, 186.5 unique users called per week, and across all 8 villages, users called for an average of 15.8 days. Although the calls were distributed throughout the day, there was a spike around noon, as children returned home from school for

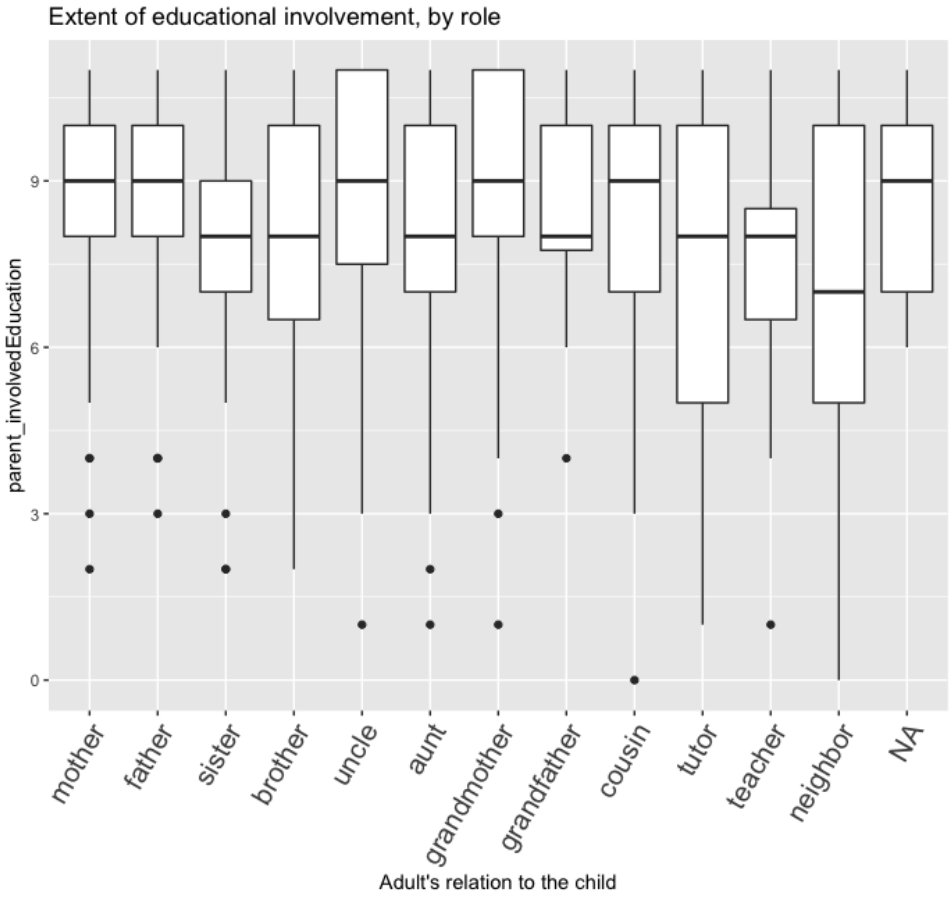


Figure 6-5: The scores on the 11 educational involvement survey items for the caregivers at the training, by their relation to the child

lunch, and again at 7:00pm and 8:00pm, perhaps as the adults who worked with the children returned home from work. See Figure 6-7 for the call times in Study 4.

For the second usage measure (2), 504/777 (65%) of children attempted (i.e., pressed a touchtone button to respond to) at least one question on a call during the study. That is, 81% of users who called (504/622) responded to at least one question throughout the study. We use this count of the number of questions attempted for all users who attempted at least one question as construct 8.2. On average, children attempted 82 questions ($SD$=142.28, $Med$=19, $min$=0, $max$=1849). In Section 6.4.3, we investigate which factors were predictive of children (1) calling and (2) attempting questions.

### 6.3.9 Construct 9: Children's curriculum progression (DV)

Children's lesson mastery is operationalized as the number of unique question types each child mastered. Progression through the 8 units of the curriculum is predicated on mastery of all of the question types in each unit. Each unit contains a fixed number of unique question types ($min$=4, $max$=9), which are provided to children until they master each one. See Table 6.4 for the total number of unique question types in each unit. After all the question types in a given unit are mastered, the children progress to the next unit. "Mastery" was defined *a priori* in the system design as correctly completing over 60% of questions of that type, above a minimum

| Item | Count (and percent) of respondents |
|---|---|
| Pay for school supplies | 651 (95%) |
| Teach domestic tasks | 642 (89%) |
| Give educational advice | 633 (93%) |
| Discipline child | 594 (87%) |
| Remind child about homework | 581 (85%) |
| Ask child about what they are learning or working on | 560 (82%) |
| Go to meetings at school | 521 (76%) |
| Help child with homework | 521 (76%) |
| Read to child | 378 (55%) |
| Communicate with teacher about child's progress via phone, SMS, or in person | 348 (51%) |
| Pay for home tutor | 284 (41%) |

Table 6.3: List of educational involvement survey items, and the count and share of respondents who reported having that involvement

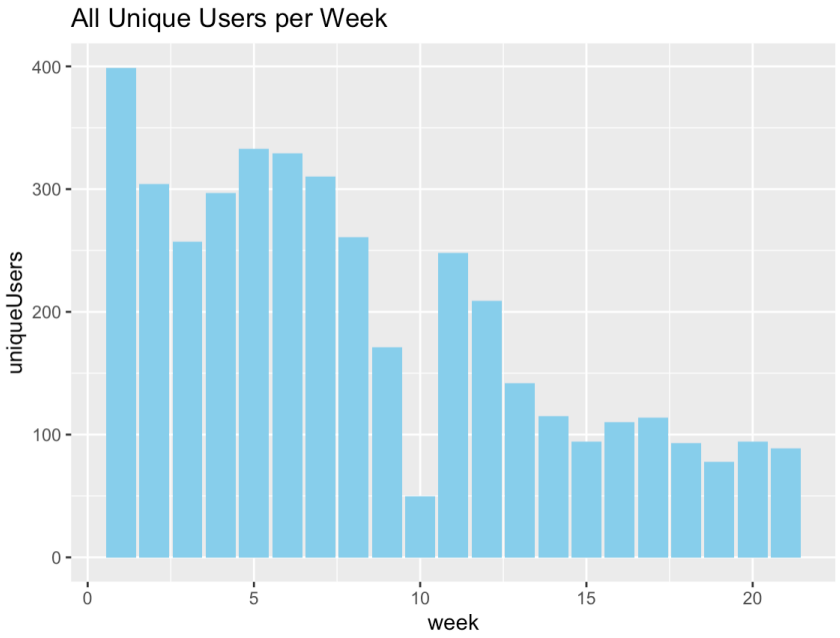


Figure 6-6: Study 4: Count of unique users calling Allô Alphabet each week (Note: the IVR server was down during week 10 due to an outage)

threshold of 15 questions completed. This is encoded in the database as a binary value of "mastery" for each question type, for each user.

Overall, the average correctness across all questions was 46%. In total, 429 of 777 children (55%) mastered at least one of the 45 question types. On average, children mastered 4.55 question types ($SD$=4.4, $Med$=3, $min$=0, $max$=45), or roughly 1 unit. In Section 6.4.4, we investigate which factors were predictive of children mastering more question types and thus advancing in the curriculum.

| Question type | Unit | Number of users | Unique questions completed | Percent correct |
|---|---|---|---|---|
| 1 | 1 | 450 | 14091 | 0.39 |
| 2 | 2 | 163 | 4770 | 0.42 |
| 3 | 1 | 446 | 19003 | 0.39 |
| 4 | 2 | 154 | 3750 | 0.42 |
| 5 | 1 | 412 | 6435 | 0.62 |
| 6 | 2 | 138 | 1810 | 0.67 |
| 7 | 1 | 427 | 13295 | 0.51 |
| 8 | 2 | 136 | 1893 | 0.59 |
| 9 | 3 | 33 | 1216 | 0.6 |
| 10 | 3 | 44 | 1040 | 0.49 |
| 11 | 3 | 45 | 1214 | 0.53 |
| 12 | 3 | 49 | 1093 | 0.54 |
| 13 | 3 | 43 | 1164 | 0.55 |
| 14 | 3 | 44 | 1000 | 0.51 |
| 15 | 4 | 13 | 312 | 0.38 |
| 16 | 4 | 13 | 261 | 0.46 |
| 17 | 4 | 2 | 21 | 0.91 |
| 20 | 4 | 2 | 22 | 0.87 |
| 21 | 4 | 10 | 276 | 0.44 |
| 22 | 4 | 2 | 22 | 0.73 |
| 23 | 4 | 1 | 26 | 0.7 |
| 24 | 5 | 2 | 36 | 0.62 |
| 25 | 5 | 7 | 219 | 0.47 |
| 26 | 5 | 14 | 338 | 0.45 |
| 27 | 5 | 15 | 230 | 0.42 |
| 28 | 6 | 13 | 381 | 0.41 |
| 29 | 6 | 4 | 39 | 0.62 |
| 30 | 6 | 3 | 74 | 0.56 |
| 31 | 6 | 4 | 41 | 0.79 |
| 32 | 6 | 4 | 69 | 0.5 |
| 34 | 6 | 1 | 17 | 0.83 |
| 37 | 7 | 1 | 15 | 0.94 |
| 38 | 7 | 1 | 5 | 1 |
| 39 | 7 | 1 | 10 | 1 |
| 40 | 7 | 1 | 15 | 0.94 |
| 41 | 7 | 1 | 3 | 1 |
| 42 | 7 | 1 | 10 | 1 |
| 43 | 7 | 1 | 17 | 0.65 |
| 44 | 7 | 1 | 16 | 0.75 |
| 45 | 7 | 1 | 105 | 0.19 |

Table 6.4: Each of the 45 question types, with number of users, number of questions completed, and percent correct

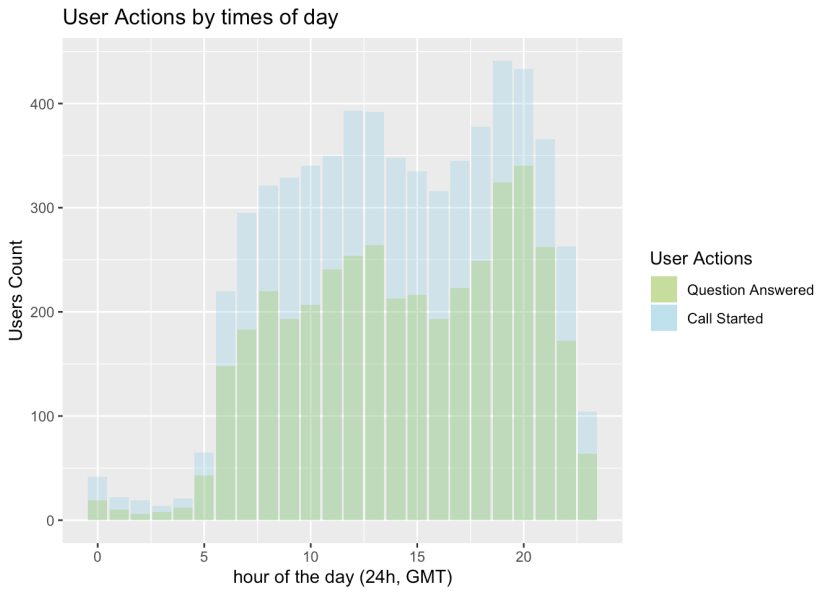


Figure 6-7: Study 4: Time of day users called Allô Alphabet

### 6.3.10 Construct 10: Adult supporter system usage (DV/IV)

Adults' system usage is operationalized by the total number of interactions users had with the 4 main menu items in the adult supporter version of the system. We sum the total number of interactions each user has for the four possible menu choices, including (1) general information about the study and purpose of developing phonological awareness, (2) personalized information about their child's usage and progress through Allô Alphabet, (3) personalized information about specific concepts their child is having difficulty with (i.e., the question type with the lowest average score in the current unit), including example questions and hints, as well as generic support messages for parents with lower literacy levels; and (4) personalized information about the specific literacy games their child has unlocked through their system usage. These interactions with the adult supporter system come from two sources, either from accessing the adult supporter system via the study phone we provided the child and choosing the adult supporter menu, or from calling the Allô Alphabet IVR number from any other non-study phone (e.g., a family member's personal phone) and typing in the phone number of their child's phone to link the account and access their child's data. However, only 6 individuals successfully connected to Allo Alphabet's adult supporter system from their personal phones, out of a total of 412 unidentified numbers that placed calls to the IVR. Of those 6, only 3 accessed any of the adult supporter information available in the system. This suggests that an easier method to connect adults to children's accounts is needed, if 412 unidentified callers attempted to link accounts with children and 406/412 were unsuccessful). We thus combine the adult supporter system usage data from these two data sources (376 users accessing the adult supporter system from the study phones and data from the 6 unknown phone numbers). Unfortunately, for both of these sources of data, we have no way of knowing who the caller was. For the unknown numbers, if they successfully connected to the child's account, then they would have needed to know the child's study phone number. For the 376 users calling from the study phone, anyone calling from that device could select the 2nd option on the main menu to access the adult support information.

In total, 382 users successfully accessed the adult supporter system (382/777 participants, or 49%). Of these, the total number of times they accessed the four adult support menu items was, on average, 26.4 times ($SD$=37.6, $Med$=15, $min$=1, $max$=459). We then break these down into the four types of menu options. For the generic information about about the study, the average number of times these items were accessed per user was 0.8 ($SD$=2.1, $Med$=0, $min$=0, $max$=18). For the information about word games they could play with their children offline, the average number of times these items were accessed was 1.5 ($SD$=2.9, $Med$=1, $min$=0, $max$=32). For the personalized information about their child's progress, the average number of times these items accessed was 13.3 ($SD$=20.5, $Med$=7, $min$=0, $max$=208). For the personalized information about ways to help with specific concepts their child is struggling with, the average number of times these items were accessed was 10.8 ($SD$=19.8, $Med$=5, $min$=0, $max$=203). This suggests that users were repeatedly calling the adult supporter system for information about children's progress and for ways they could help. Considering that the mean number of calls made to the child-facing version of the system was 67.5, users were accessing the adult support information on 1 out of every 5 or 6 calls. See Figure 6-8 for the distribution of the unique menu items (up to 4) accessed by users.

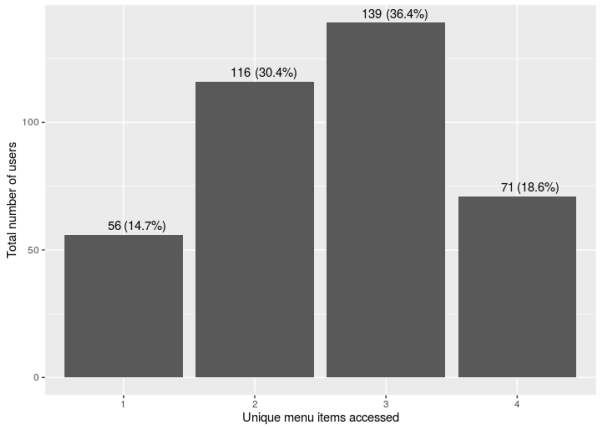


Figure 6-8: The total number of unique menu items accessed in the adult supporter system

## 6.4 Findings: Regression Models

### 6.4.1 Summary indices

Because the independent variable constructs each contained multiple sub-items, we created a "summary index" that would capture each of the various sub-items in a composite score that could be scaled (i.e., with a z-score) and included in a model. We will use this method for calculating a summary index for constructs 1-5 and 7. Construct 6 is simply a z-score of the total of the 11 parental involvement items, and thus does not require a summary index.

Constructs are estimated as summary index variables, following the method of Anderson [10, 92]. Briefly, this method converts each measurement to a z-score, and an index is estimated as the weighted average of these scores, where the weights are determined by the inverse of the covariance matrix of the transformed measures. The index estimate is performed as follows, paraphrasing from Anderson [10]:

- Reverse-coded measures (i.e., higher is worse) are sign-switched so that positive is always

better for all measures,

- Each measure is z-scored using the overall mean and the standard deviation.
- For a group of outcomes that will be combined into a single index, calculate the covariance matrix across all participants.
- For each participant, compute the index score as a function of the z-scored outcome measures, as in [10].

### 6.4.2 Hypotheses

Although many of our hypotheses for RQ1 (effect of child-level and family-level factors on system usage) are similar to those in the OSF pre-registration[3], the numbering of many research questions and constructs have changed since the pre-registration was posted, and other constructs and research questions (RQ2 and RQ3) have since been added. I list here the hypotheses for clarity.

**RQ1**

- H4.1.1. Children's baseline literacy (Construct 1) will be positively associated with both children's literacy system usage DVs.
- H4.1.2. Children's baseline language ability (Construct 2) will be positively associated with both children's literacy system usage DVs.
- H4.1.3. Household French language and literacy (Construct 3) will be positively associated with both children's literacy system usage DVs.
- H4.1.4. Household socio-economic status (Construct 4) will be positively associated with both children's literacy system usage DVs.
- H4.1.5a. Children's participation in agricultural activities (Construct 5) will be negatively associated with both children's literacy system usage DVs.
- H4.1.5b. Children's participation in domestic labor activities (Construct 5) will be positively associated with both children's literacy system usage DVs.
- H4.1.6. Family educational involvement (Construct 6) will be positively associated with both children's literacy system usage DVs.
- H4.1.7. Household technology experience (Construct 7) will be positively associated with both children's literacy system usage DVs.

**RQ2**

- H4.2.1. Children's baseline literacy (Construct 1) will be positively associated with children's lesson mastery.
- H4.2.2. Children's baseline language ability (Construct 2) will be positively associated with children's lesson mastery.

[3]https://osf.io/n53w8?view_only=6055dd7d46394a4c821f9e6015e1bd7c

- H4.2.2. Household French language and literacy (Construct 3) will be positively associated with children's lesson mastery.
- H4.2.3a. Children's participation in agricultural activities (Construct 5) will be negatively associated with their lesson mastery.
- H4.2.3b. Children's participation in domestic labor activities (Construct 5) will be positively associated with their lesson mastery.
- H4.2.4. Household socio-economic status (Construct 4) will be positively associated with children's lesson mastery.
- H4.2.6. Household technology experience (Construct 7) will be positively associated with children's lesson mastery.

**RQ3**

- H4.3.1. Household French language and literacy (Construct 3) will be positively associated with adults' system usage.
- H4.3.2. Household socio-economic status (Construct 4) will be positively associated with adults' system usage.
- H4.3.3. Adults' system usage (Construct 10) will be positively associated with children's system use (Construct 8.1 and 8.2). However, the alternative hypothesis (i.e., negatively associated) could be possible, if adults use the adult supporter system less if they feel their children are able to independently use the system without their support (as in our findings from Study 3 [149]).
- H4.3.5. Adults' system usage (Construct 10) will be positively associated with children's lesson mastery (Construct 9).

### 6.4.3 RQ 1: Children's System Usage

#### Data preparation

In this research question, we investigate the effect of the different factors (e.g., constructs 1-7) on children's system usage, operationalized in two different ways. I thus conducted two regression models, one for each of the two usage constructs. Before running the models, I wanted to validate the approach. Given the high value of zero data (as seen in Figure 6-9), a "tobit" regression model was appropriate, as they are designed to deal with "left-censored" data (or, data with large numbers of items on either the left or the right end of the scale), such as we have [236].

Then, I evaluated the prevalence of collinearity among our independent predictor variables before running the models (as recommended by [153]). To do this, I generated a correlation matrix to understand the collinearity of the predictor variables (i.e., constructs 1-7) and outcome variables (i.e., constructs 8-10). See Figure 6-10 for the correlation levels of these constructs. Construct 1 (children's baseline literacy) and 2 (children's baseline language) have moderately high correlation ($\rho = 0.52$), and construct 3 (family language/literacy) and construct 4 (household SES) have a moderate correlation ($\rho = 0.42$). Thus any significant estimates of those constructs should be interpreted with caution. Within the outcome measures, the three primary outcome constructs, 8.1 (number of calls to Allô Alphabet), 8.2 (number of questions

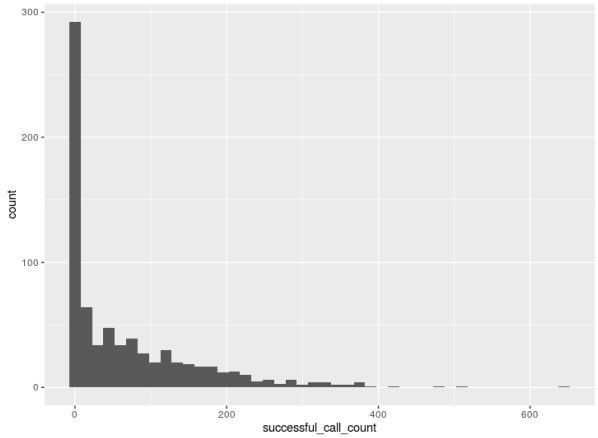


Figure 6-9: The number of calls placed to Allo Alphabet, per user

attempted, and 9 (number of lessons mastered), have high correlation amongst each other ($\rho = 0.62$ for 8.1 and 8.2; $\rho = 0.58$ for 8.1 and 9; $\rho = 0.69$ for 8.2 and 9). In addition, there is high correlation among the four adult system usage measures that comprise construct 10 (progress information, lesson support, game instructions, and study information), with moderately high correlation between construct 8.2 (questions attempted) and each of these sub-measures of construct 10.

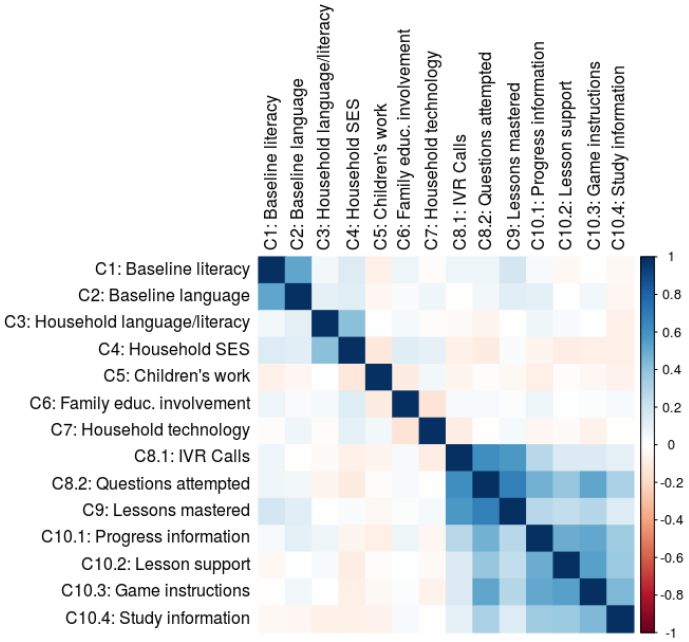


Figure 6-10: Correlation matrix of the 7 predictor constructs, and the 3 outcome constructs (with subconstructs)

| Factor | Estimate | Std. Error | z value | p value |
|---|---|---|---|---|
| **Baseline literacy** | **28.04965** | **12.42274** | **2.258** | **0.0240 *** |
| Baseline language | -1.39325 | 12.95553 | -0.108 | 0.9144 |
| Family language/literacy | 3.46914 | 17.55182 | 0.198 | 0.8433 |
| **Household SES** | **-34.87979** | **14.74797** | **-2.365** | **0.0180 *** |
| **Children's work** | **-67.23100** | **38.50319** | **-1.746** | **0.0808 .** |
| Gender | -6.00572 | 16.51733 | -0.364 | 0.7162 |
| Family educational involvement | -6.01676 | 9.26070 | -0.650 | 0.5159 |
| Household phone/IVR | -12.91402 | 15.46605 | -0.835 | 0.4037 |
| **any_issues1** | **29.88728** | **18.08477** | **1.653** | **0.0984 .** |
| Children's work:Gender | 29.25424 | 22.21904 | 1.317 | 0.1880 |

Table 6.5: RQ1.1 (Calls): Tobit linear regression model results

| Factor | Estimate | Std. Error | df | t value | p-value |
|---|---|---|---|---|---|
| **Non-hazardous agricultural work** | **-0.226104** | **0.118810** | **213.623741** | **-1.903** | **0.0584 .** |
| **Hazardous agricultural work** | **0.255751** | **0.119323** | **214.689106** | **2.143** | **0.0332 *** |
| Domestic work | 0.016427 | 0.068488 | 216.175132 | 0.240 | 0.8107 |
| **Commercial work** | **-0.145848** | **0.070958** | **217.586289** | **-2.055** | **0.0410 *** |

Table 6.6: RQ1.1 (Calls): Post-hoc analysis of construct 5's composite score

### RQ 1.1: Number of calls to Allo Alphabet

For RQ1.1 (the number of calls placed to Allo Alphabet), I conducted a tobit regression model, with the 7 constructs (1-7) as the independent variables, and construct 8.1 as the dependent variable. See Table 6.5 for the results. The significant factors were construct 1 (children's baseline literacy) ($p<0.05$) and construct 4 (family SES, education, and occupation) ($p<0.05$), with marginal significant factors of construct 5 (children's work activities) ($p<0.1$) and the binary variable of technical issues ($p<0.1$). In other words, children's baseline literacy and having more self-reported technical issues were positively associated with calling the IVR, while increased SES and parental education and increased children's work activities were both negatively associated with calling the IVR.

Then, to investigate which elements of these composite factors were significant, I conducted a post-hoc model of the sub-items within each summary index composite. Following the recommendation from Anderson [10], the process I used for each one was to first (1) remove each significant composite from the model and re-run it to obtain the residuals; then (2) regress each of the sub-items within each composite against the residuals from that new model to identify which of these were significant.

For constructs 1 and 4, none of the composite's sub-items were significant. For construct 5, working in hazardous cocoa activities was a significant, positive predictor of calling the IVR ($p<0.05$), while working in local commercial activities was a significant, negative predictor ($p<0.05$) of calling the IVR. See Table 6.6 for the results of this post-hoc analysis for construct 5. The finding about children's baseline literacy being positively associated with calling confirms our hypothesis (H4.1.1). However, the finding about construct 4 (SES, and parental education and occupation) being negatively associated with calling was contrary to our hypothesis (H4.1.4), as was the finding about children's participation in hazardous cocoa labor being positively associated with calling (H4.1.5a). Participation in non-hazardous cocoa activities was negative (in line with our hypothesis H4.1.5a), but was marginally significant (p=0.0584).

| Factor | Estimate | Std. Error | df | t value | p-value |
|---|---|---|---|---|---|
| Baseline literacy | 0.15263 | 0.15034 | 135.47841 | 1.015 | 0.31181 |
| Baseline language | 0.04862 | 0.15765 | 147.03008 | 0.308 | 0.75822 |
| Family language/literacy | -0.11748 | 0.22772 | 148.39021 | -0.516 | 0.60670 |
| **Household SES** | **-0.40754** | **0.18334** | **149.43932** | **-2.223** | **0.02772 *** |
| **Children's work** | **-1.25491** | **0.47605** | **149.07133** | **-2.636** | **0.00927 **** |
| Gender | -0.23479 | 0.19914 | 149.24317 | -1.179 | 0.24026 |
| **Family educational involvement** | **0.19981** | **0.11497** | **123.63630** | **1.738** | **0.08470 .** |
| Household phone/IVR | 0.14149 | 0.19103 | 143.43964 | 0.741 | 0.46010 |
| **Children's work:Gender** | **0.70160** | **0.27441** | **149.94786** | **2.557** | **0.01156 *** |

Table 6.7: RQ1.2 (Questions): Hierarchical linear regression model results

| Factor | Estimate | Std. Error | df | t value | p-value |
|---|---|---|---|---|---|
| Non-hazardous agricultural work | -0.09451 | 0.19722 | 152.55088 | -0.479 | 0.632 |
| Hazardous agricultural work | 0.24672 | 0.20263 | 152.72132 | 1.218 | 0.225 |
| Domestic work | -0.02861 | 0.10630 | 152.08822 | -0.269 | 0.788 |
| **Commercial work** | **-0.19699** | **0.10639** | **153.66407** | **-1.852** | **0.066 .** |
| Gender | -0.28400 | 0.20359 | 153.79975 | -1.395 | 0.165 |

Table 6.8: RQ1.2 (Questions): Post-hoc decomposition of construct 5

#### RQ 1.2: Number of questions attempted

Then, to investigate RQ 1.2 (the number of questions children had attempted in Allô Alphabet), I conducted a hierarchical linear regression model, where the fixed effects were the 7 constructs (1-7), with a random effect of the village, and with construct 8.2 (number of questions attempted) as the dependent variable. See Table 6.7 for the results.

The significant predictors were construct 4 (SES, and parental education and occupation) ($p<0.05$), construct 5 (children's work activities) ($p<0.01$) and the interaction between construct 5 and gender ($p<0.05$), with a marginally significant factor of construct 6 (family involvement) ($p=0.08$). Then, after running the same post-hoc decomposition of the constructs, for construct 4, none of the composite's sub-items were significant. For construct 5, work in local commercial activities was a marginally significant, negative predictor ($p<0.1$) of attempting questions. See Table 6.8 for the results of this post-hoc analysis for construct 5. In other words, increased family SES (contrary to our hypothesis H4.1.4, as in RQ1.1) and increased children's commercial work activities were both negatively associated with the number of questions attempted, while family educational involvement was positively associated with the number of questions attempted.

### 6.4.4 RQ 2: Children's Lesson Mastery

For this research question, we investigate the effect of different child-level and family-level factors (i.e., constructs 1-7) on children's progression through the Allo Alphabet curriculum, operationalized as the number of unique question types (out of 45 across the 8 units) they have mastered (defined as greater than 60% accuracy on more than 15 unique questions). Because this construct was also left censored—that is, only 429 out of 777 participants mastered at least one trial—I also ran this as a tobit regression model, similar to RQ 1.1. The results can be seen in Table 6.9.

The only significant predictor of the number of question types mastered was construct 1 (children's baseline literacy level) ($p<0.01$). That is, as hypothesized (H4.2.1) children who

| Factor | Estimate | Std. Error | z value | p-value |
|---|---|---|---|---|
| **Baseline literacy** | **1.75272** | **0.65347** | **2.682** | **0.007314 **** |
| Baseline language | -0.14858 | 0.69916 | -0.213 | 0.831707 |
| Family language/literacy | 0.87791 | 0.99792 | 0.880 | 0.379004 |
| Household SES | -1.00253 | 0.79846 | -1.256 | 0.209267 |
| Children's work | -3.07835 | 2.12435 | -1.449 | 0.147315 |
| Gender | -0.58581 | 0.87457 | -0.670 | 0.502971 |
| Family educational involvement | 0.16093 | 0.49461 | 0.325 | 0.744910 |
| Household phone/IVR | 1.26816 | 0.88577 | 1.432 | 0.152231 |
| any_issues$_Y$ | 0.50227 | 0.97366 | 0.516 | 0.605952 |
| Children's work:Gender | 1.79140 | 1.21750 | 1.471 | 0.141189 |

Table 6.9: RQ2 (Curriculum mastery): Tobit linear regression model results

| Factor | Estimate | Std. Error | df | t value | p-value |
|---|---|---|---|---|---|
| French letter | 0.649176 | 0.575824 | 146.560997 | 1.127 | 0.26142 |
| **French word** | **3.201835** | **1.037554** | **146.920513** | **3.086** | **0.00243 **** |
| **French pseudo-word** | **-2.709011** | **0.979970** | **145.287856** | **-2.764** | **0.00644 **** |

Table 6.10: RQ2 (Curriculum mastery): Post-hoc decomposition of construct 1

had higher baseline levels of literacy were more likely to master lessons and progress in the curriculum. To investigate which specific literacy items were predictive of mastering skills, I conducted the same decomposition of the composite for construct 1 described in RQ 1. See Table 6.10 for the results. The score on identifying written French words was significantly positively associated with mastering more lessons ($p<0.005$), while the score on identifying French pseudo-words was significantly negatively associated with lesson mastery ($p<0.005$).

### 6.4.5 RQ 3: Adult Support System Usage

Then, to investigate RQ3 (usage of the adult supporter system), I ran three analyses. First (1), I investigated the household factors predictive of a user accessing menu items in the adult supporter system. Then, I investigated how users' interaction with the adult supporter menu items was associated with children's (2) calls, (3) questions attempted, and (4) number of lessons mastered.

For the first analysis (RQ3.1), because of the left-censored nature of adult supporter system usage (i.e., only 52% of users ever had someone access the adult supporter system), I ran a tobit regression model, using as predictors construct 3 (household language and literacy), construct 4 (household SES), construct 6 (family educational involvement) and construct 7 (family technology usage), with the dependent variable as the total number of menu items accessed in the adult supporter system. None of the predictors were significant. See Table 6.11.

Then, to understand how usage of the adult supporter system was associated with children's usage (i.e., calls and questions) and mastery, I conducted three tobit regression models. For each of these, the four independent variables were the same—the individual totals for each of the four menu items: generic information about the study, personalized information about children's usage and progress, personalized information about how to provide support for concepts children were having performance issues with, and generic information about word games that their children had "unlocked" through their usage. The dependent variables were: the total number of calls (RQ3.2), total number of questions attempted (RQ3.3), and total number of skills

| Factor | Estimate | Std. Error | z value | p-value |
|---|---|---|---|---|
| Family language/literacy | 0.7798 | 0.4870 | 1.601 | 0.109 |
| Household SES | -0.2395 | 0.4040 | -0.593 | 0.553 |
| Family educational involvement | -0.1493 | 0.2545 | -0.587 | 0.557 |
| Household phone/IVR | -0.2003 | 0.4425 | -0.453 | 0.651 |

Table 6.11: RQ3.1 (Adult Supporter System): Tobit linear regression model results for factors predicting adult supporter system usage

| Factor | Estimate | Std. Error | z value | p-value |
|---|---|---|---|---|
| **Child's progress information** | **0.40985** | **0.09752** | **4.203** | **2.64e-05 *** ** |
| Lesson support information | 0.05934 | 0.09996 | 0.594 | 0.553 |
| Game information | 0.02945 | 0.10501 | 0.280 | 0.779 |
| Phonology and research study information | -0.04228 | 0.09302 | -0.455 | 0.649 |

Table 6.12: RQ3.2 (Calls): Tobit linear regression model results for adult system usage on number of calls

mastered (RQ3.4), respectively.

For RQ3.2, having someone accessing the progress information was significantly positively associated with the user placing more calls to Allo Alphabet ($p<0.001$). See Table 6.12 for the results.

For RQ3.3, having someone access the progress information ($p<0.001$) and the game information ($p<0.001$) were both significantly, positively associated with more questions attempted. See Table 6.13 for the results.

Finally, for RQ3.4, having someone access the progress information ($p<0.05$) and the game information ($p<0.05$) were both significantly, positively associated with more question types mastered. See Table 6.14 for the results.

For all of these results, ideally, we would know something about the user who accessed it (i.e., whether it was the child or an adult, and which adult it was). It may be the case that children using Allô Alphabet were themselves accessing the adult supporter system on their own phones, that adults within the family were using it to get such information, as intended, or it may be equally possible that other adults in the community, such as tutors and teachers, were using the child's phone to access this information. Further, for each of these users, it would be beneficial to know what other offline support behaviors these adults were engaging in. That is, after they heard the message telling them about children's progress in the system, how did they use that information? Did they encourage the child to continue using it if there were gaps, or try to resolve obstacles to children's use? After they listened to the lesson support information, which provided them with the specific skill the child had had the most difficulty

| Factor | Estimate | Std. Error | z value | p-value |
|---|---|---|---|---|
| **Child's progress information** | **0.42009** | **0.10759** | **3.905** | **9.43e-05 *** ** |
| Lesson support information | 0.01386 | 0.11119 | 0.125 | 0.900824 |
| **Game information** | **0.49142** | **0.14442** | **3.403** | **0.000667 *** ** |
| Phonology and research study information | 0.06307 | 0.09820 | 0.642 | 0.520722 |

Table 6.13: RQ3.3 (Questions): Tobit linear regression model results for adult system usage on number of questions attempted

| Factor | Estimate | Std. Error | z value | p-value |
|---|---|---|---|---|
| **Child's progress information** | **0.72912** | **0.33588** | **2.171** | **0.0299 *** |
| Lesson support information | 0.30859 | 0.38154 | 0.809 | 0.4186 |
| **Game information** | **0.92321** | **0.44163** | **2.090** | **0.0366 *** |
| Phonology and research study information | -0.17588 | 0.29395 | -0.598 | 0.5496 |

Table 6.14: RQ3.4 (Curriculum mastery): Tobit linear regression model results for adult system usage on number of question types mastered

with, and gave examples and hints on how to answer questions about that skill, did they then use that information to teach that skill to their child themselves? Unfortunately, we do not have either 1) identifying information about the user who accessed the adult support system, and 2) quantified information about how adults helped children use Allô Alphabet during Study 4. The current plan is to provide a set of survey items to children (or adults, if possible) at the post-test and phone collection in October, 2020, asking about the nature and extent of the support adults provided to children while using Allô Alphabet. Then, analyses could be conducted to investigate that relationship between use of the adult support system, and the actual involvement of family members with children's use of Allô Alphabet.

### 6.4.6 Addendum: System Usage During COVID-19 School Closures

In March 16th, 2020, Côte d'Ivoire closed schools across the country in response to the coronavirus pandemic, and would not re-open again until May 15th, 2020. As in Study 3, when schools across Côte d'Ivoire closed due to teacher strikes, we wanted to understand how this impacted children's use of Allô Alphabet. This is a much wider issue, and beyond the scope of this dissertation, as nearly 1.25 billion students across 165 countries have been impacted across primary, secondary, and tertiary education systems [16] as of the time of writing. In higher education, many institutions shifted to distance learning remarkably quickly in the wake of campus closures, while K-12 systems have adapted in a variety of ways [194]. However, the widespread enthusiasm for online learning during COVID-19 is belied by the reality of many students' lives. Across the world, some students were able to access online learning efforts on modern personal laptops, stable broadband internet, and parents or other adults who are working-from-home. Meanwhile, others logged in to virtual classrooms from smartphones in crowded apartments or sat in their cars within range of their school's wifi, while their parents worked on farms, grocery stores, and gas stations—if they had access to internet-connected devices at all, or time available to learn, free from caregiving responsibilities.

In Côte d'Ivoire, the Ministry of Education (*Ministère de l'Éducation nationale, de l'Enseignement technique et de la Formation professionnelle*, MENETFP) issued a communique informing the "parents of students, educational community, partners in the education system, the press, and the national and international community" of their approaches to ensure the continuity of learning during the pandemic. See Figure 6-11 for an image of their communique sent out to families. They describe courses available for free online, others accessible via SMS, and others on the radio and on TV (evocative of the national educational TV initiative in the 1980s described in Chapter 5, which was one of the provocations for the first national teacher strike in Côte d'Ivoire). The online courses appeared to be limited to a pdf version of the textbook embedded in a website; something that would be inaccessible to nearly all students in the rural communities, given the lack of access to Internet (6.9%) or data on smartphones. Additionally, as MENETFP notes in the communique, these courses were available only for students in the classes about to take

the exams (CM2, Troisième, and Terminale), while other grades would be "*pris en compte progressivement*" [gradually taken into account], but did not appear to have been developed at the time of this writing in June, 2020.

MINISTERE DE L'EDUCATION NATIONALE,
DE L'ENSEIGNEMENT TECHNIQUE
ET DE LA FORMATION PROFESSIONNELLE

REPUBLIQUE DE COTE D'IVOIRE
Union-Discipline-Travail

**COMMUNIQUE**

Afin d'éviter la propagation du coronavirus (COVID-19) en Côte d'Ivoire, le Conseil National de Sécurité (CNS) a décidé la fermeture de tous les établissements scolaires pour une période de 30 jours, depuis le lundi 16 mars 2020 à minuit.
Pour assurer la continuité de l'Ecole, le Ministère de l'Education Nationale, de l'Enseignement Technique et de la Formation Professionnelle informe les parents d'élèves, la communauté éducative, les partenaires du système éducatif, la presse, la communauté nationale et internationale, qu'il organise des cours au bénéfice des élèves à partir du **mardi 31 mars 2020.**
Ces cours sont accessibles **gratuitement** en ligne, par SMS, à la télévision et à la radio.
Ils concernent dans un premier temps les élèves des classes **d'examen (CM2, Troisième et Terminale).**
Les autres niveaux seront pris en compte progressivement.

Les Sites pour accéder aux cours sont :
- **www.ecole-ci.online ;**
- **www.ecoleweb.mysonec.com ;**

**Par Facebook sur la page EDUC TV**
**www.facebook.com/EducationTele**

**Par SMS**
- ENVOYER **edu par sms au 98051**

- Les **horaires** de cours à la **Télévision** et à la **Radio** :

**Télévision :**
**RTI 1 : 15 H 30 - 16 H 00**
**RTI 2 : 09 H 00 - 11 H 00**

**Radio :**
**Fréquence 2 : 15 H 00 -16 H 00**
**Radio CI : 08 H 00 – 08 H 30**

**« Ecole fermée, cahiers ouverts »**

Figure 6-11: Official communique from the Ivorian Ministry of Education on continuity of learning during COVID-19

During this time, our platform, Allô Alphabet, was still available for families to use during the COVID-19 school closures, on devices which we provided to the families, and targeting students in CM1. We thus wanted to understand how families were continuing to use it for learning during the COVID-19 school closures. In Study 3 (Chapter 5), during the teacher strike school closures (which lasted for an equivalent 2-month period in January-February 2019), we found that although there was an equivalent amount of usage during the strike compared with the non-strike school period, the nature of that usage varied, with many adult family members telling us of their inability to monitor their children's learning during a teacher strike, despite their desire for children to continue learning.

In Study 4, after schools closed for COVID-19, several Ivorian members of our team called each participating family to ask about (1) whether they were experiencing any technical issues (discussed at more length above in Section 6.2.3) and (2) whether any other factors had impacted children's use of Allô Alphabet. They called 728 of the 777 participants (94%), all of those who gave us a phone number for an adult in the family who could be contacted at the start of the study. Of these, 532/728 (73%) were able to be reached on these calls. The other 196, despite repeated attempts, were unable to be reached. Of those who could be reached, 48 (of 532, or 9%) reported that school closures due to coronavirus had impacted their child's use of Allô

Alphabet.

In some cases (35 of 532, or 6.5%), these respondents report that the parent or other adult kept the phone [*confisqué* or *gardé*] "because of the coronavirus". Other respondents revealed that when school was canceled, the adults ceased having their child learn with Allô Alphabet, saying that "the child no longer calls because of the coronavirus, for being on leave he should not call" (P2708). In many of these cases, this cessation of learning was because the child went to the farm (*camp*) with the parents or adults to work (45 of 532, or 8.5%), and did not have access to the phone to learn, or, while in the field, did not have sufficient network coverage to make a call to the IVR. As one respondent told us, "these times the child cannot do his exercises due to field work but will do them next week." (P1132). Despite going to the field to work, some participants were still learning with their tutors, but were not using Allô Alphabet, as this respondent shared, "the child stops calling, he is at the camp with his tutor since the end of classes." (P3025). In other cases, which were the minority, this cessation of learning was because the phone was left with the teacher, and when schools closed, it was no longer accessible.

> "The phone is with the teacher since the lessons stopped so he stops calling" (P1653)
>
> "The child stops calling since the end of classes, because his phone is with his teacher." (P1116)

Thus, while the school closures due to COVID-19 may not have been a primary factor impacting participants' ability to call, it is clear from the reports of these 48 participants that the same factors described throughout Study 4 were at work in impacting their likelihood to use Allô Alphabet. That is, as the adults largely were responsible for mediating children's access to the mobile phone to call the IVR, their co-location with their parents or other family adults was likely to impact their ability to use and access Allô Alphabet. Moreover, the children and their adults' movement between the villages and the *camp* was a factor impacting children's use of Allô Alphabet, as we saw in Study 3 (Chapter 5). We will discuss these issues at length in the Discussion in Chapter 7.

## 6.5 Discussion

In this chapter, we identify factors associated with participants calling the IVR system, attempting more questions, and mastering more of the curriculum in a second longitudinal study, with 777 participants across 8 villages, for 21 weeks (and still ongoing at the time of writing).

We find that children's baseline literacy was positively associated with calling more and mastering more of the curriculum (though not with attempting more questions). While this is an indication of the "rich (in literacy) get richer" effect, when it came to the actual SES of the participants, we saw the opposite effect, contrary to our hypothesis H4.1.4, where those with lower SES and parental education were more likely to call and attempt more questions (though not more likely to master more of the curriculum). One hypothesis for why children in higher SES families called the system less may be that those families were more likely to hire private tutors, and thus had less need for ed tech to help support children's learning, or that those children had other technology available, either for learning or entertainment (e.g., television, radio, etc). However, given that this finding is contrary to our finding in Study 3 that children in families with higher SES were more likely to call, this warrants further investigation.

Our findings about the relationship between children's work activities and educational technology system usage were complex, contradictory, and warrant further investigation. First, we

saw an unexpected positive association between participation in hazardous cocoa activities (e.g., spreading fertilizer or chemicals, spraying insecticides, or cutting or burning trees (see [230] for more detail)) and number of calls made, and a (marginally significant) negative association for non-hazardous cocoa activities (e.g., planting seeds, plucking cocoa pods, gathering, breaking, and heaping cocoa pods, drying them in the sun, etc) with number of calls. In addition, we saw a negative association between the number of commercial activities (e.g., managing or running a family business) with number of calls made and questions completed. One hypothesis might be that the hazardous cocoa activities do not take as long to complete, or are not done as frequently as the non-hazardous activities or commercial activities. An alternative hypothesis is that families who ask children to complete hazardous tasks may also give those children more responsibility or autonomy in holding onto and using the mobile device to access Allô Alphabet, or, more simply, those children may be older. For the second hypothesis, I conducted a post-hoc test of the relationship between the child's age and hazardous activities, finding a significant, though weak, correlation ($\rho = 0.21$, $p<0.001$), however, there was no significant relationship between age and the number of calls, suggesting another factor at work.

Finally, we found evidence throughout Study 4 for the significant, positive impact of families' involvement in education on children's successful, sustained use of an educational technology, Allô Alphabet. First, we saw a positive (albeit marginally significant) relationship between the total score on the family involvement questionnaire and the total number of questions attempted, suggesting quantitative evidence for the benefits of the family involvement heard about in Study 1 and observed with the IVR in Studies 2 and 3. As the survey was given at the beginning of the study, it did not ask about the extent of support provided for Allô Alphabet, but a planned survey at the endline assessment intended for October 2020 will ask that. In addition, we saw evidence that use of the adult supporter system was positively associated with children calling, attempting more questions, and mastering more skills. While this may be attributed to the same effect of the previous finding—that having involvement from an adult family member is beneficial in itself—the fact that only some of the adult support menu items (specifically, the personalized progress information and game instructions) were significantly associated with the usage and progress outcomes suggests that the content of those messages was beneficial in motivating usage and (for RQ3.4) mastery of the content in the curriculum. However, as we saw evidence for in the individual calls to the families during school closures due to COVID-19, the movement of many families across villages and between the village and the *camp* may have impacted the availability of adult supporters, and, when those adults were the ones who kept the phone (as in the 80 participants (of 532 respondents, or 15%) whose caregivers kept the phone and were not co-located with the children). Moreover, as mentioned in Section 6.4.5, the identity of the user who accessed the adult supporter system was unknown, and potentially included the private tutors or teachers. As we saw in the survey at the beginning of Study 4, for some children (4.1%), the adult who went to the session to receive the phone and take the training on how to use it was the tutor (2.4%, or 19/777) or a teacher (1.7%, 13/777). As we heard in the follow-up calls during COVID, several of the respondents reported that the teacher had kept the phone, and so they may have been the ones calling the adult supporter system. While this might have led to more targeted support from the teacher for the skills or concepts the children needed the most support on, mutual distrust between families and teachers in some contexts (as we heard about in Study 1) may have presented challenges for meaningful family support for children's use of Allô Alphabet. In the next chapter, we discuss the larger implications of the findings in this study, as well as make connections across the 4 studies in this dissertation, and the broader implications of these findings.

# Chapter 7

# Discussion and Conclusion

## 7.1 Summary of Studies

In this thesis, I have engaged in an iterative, longitudinal design-based research program, comprising four studies in multiple communities in rural Côte d'Ivoire over the course of two and a half years. These studies have set out to understand how a technology might be designed to support Ivorian families' home literacy practices and ultimately improve their children's French literacy outcomes. In Study 1 (Chapter 3), I conducted a series of design sessions with family members, children, and teachers, to identify a set of desires, goals, and concerns for a literacy support technology [148]. Then I led our design team in translating these findings into system requirements for our partners at Eneza Education, which used those requirements to build Allô Alphabet to deliver the French literacy curriculum developed by our collaborators at the University of Delaware.

In Study 2 (Chapter 4), we deployed Allô Alphabet in a short deployment in one class in one village, to understand how families were involved with their children's use of Allô Alphabet. We found that families leverage a variety of adult supporters who provide synchronous and asynchronous support methods including direct instruction of the phonology skills as well as the digital literacy skills needed to use the IVR and SMS components of the system [145].

Then, in Study 3 (Chapter 5), we deployed Allô Alphabet in 8 rural communities for 3 months in 2019 to understand how this family support changed over time. We found that families leveraged these networks of other adult supporters to compensate for gaps in the availability of parents, but that this collective support often transitioned into more independent learning from the children, for a variety of reasons [149].

Finally, in Study 4 (Chapter 6), I used survey and system usage data from a second longitudinal study in spring 2020 to understand how individual and household factors such as language, literacy, technology ownership, and participation in labor were associated with children's use of the Allô Alphabet IVR system and progress through its curriculum. I found that children in families with lower SES and more family involvement in education called and completed more questions with Allô Alphabet, and that children who had someone access information on the adult support platform about children's progress and literacy games were more likely to call, complete questions, and master lessons in the Allô Alphabet curriculum. In the next sections, I discuss some reflections on the overarching themes and contributions of this dissertation.

## 7.2 Contributions

### 7.2.1 Scaffolding collective family support for/with literacy technologies

One major set of findings across the studies in this dissertation suggests that families in rural Ivorian communities leverage collective networks of supporters to foster children's literacy—networks which existed prior to our deployment of Allô Alphabet, and which were explicitly leveraged to support children's use of an educational technology at home. These findings contribute to learning science research by providing insights into the role that learning technologies may play in the dynamics of family literacy learning in multilingual communities.

#### Collective (though contested) support for literacy learning

This dissertation advances the literature on early literacy research that emphasizes the role of parents [212, 136, 133, 183] and siblings [198, 199, 200, 154, 88] in supporting children's learning by **identifying how a collective network of family members support children's literacy learning with technology**. Prior work has identified how family members guide children in learning culturally relevant tasks, often including farming practices [199, 198, 200, 154]. By contrast, in their recent work on tablet-based learning at home, Uchidiuno et al. found that siblings and adults often took a more hands-off role in children's learning, stepping in to help only when asked [229]. Indeed, despite the wealth of research on the critical role parents and other family members play, designers of educational technologies often focus on the child as the sole user of the technology [186, 187, 174, 127, 106].

In Côte d'Ivoire, as in many other contexts in the Global South [154, 199], children's educational development is supported by multiple members of the family and the larger household (*ménage*). We saw evidence for this across all four studies, with qualitative descriptions of the ways in which all family members "bring their grain of salt" to support the development of the child (Study 1) [148, 145, 149], as well as quantitative evidence from our survey in Study 4 for the benefits of this distributed family educational involvement across 12 different types of relations in the family and larger household, including cousins and neighbors (Figure 6-5). This is aligned with research in other sectors in Côte d'Ivoire on the nature of collective family support, including support for family health [33] and financial resources [18, 71, 120], and family farming [201]. In Ivorian farming communities, as the cost for hiring laborers during the harvest season may be prohibitively expensive, family members who are old enough may be recruited to help support the family's agricultural efforts, often carrying food, water, or supplies to the parents working in the fields [201, 207], as we saw in Study 4 (Chapter 6), and which others have identified in family cocoa farming in rural Ivorian communities [201].

In this dissertation, we find that families used these collective support networks to model and instruct children on how to use a voice-based technology designed to foster phonological awareness. We observed this in home observations repeatedly in Studies 2 and 3, and we found evidence that this support had positive impacts on students' educational technology usage in both Study 2—where children with a family supporter correctly completed a greater percentage of questions—and Study 4, where children with greater family educational involvement and use of the adult support system called the IVR more often, and attempted more questions and mastered more skills.

While this collective support was beneficial, one consequence of this collective support for children's literacy education was that family members in these support networks had different—and often contested—educational goals and methods for supporting children's literacy. As Kumar et al. point out in their work on aspirations-based design, teachers and parents in their

study context in rural India often had conflicting aspirations for girls' technology access, making the point that while aspirations are embedded in communities, they may not be shared across multiple stakeholders in those communities [129]. We find evidence for these collective aspirations for education, and using educational technology (e.g., the aspirations for children's "evolution" and "advancement" we heard about in Studies 1-3 [148, 145, 149]), and we extend this prior research to identify how these collective—and contested—aspirations (and values, beliefs, and practices) within families and households shaped family members' roles in supporting children's educational development. For instance, family members often had contested values about whether children of this age range (8-12 years old) should use mobile phones to learn, and whether and how they should be supported in doing so (which I unpack further in the next section).

**Scaffolding collective family support for literacy technology**

This dissertation advances prior literature on designing interventions [219, 107, 246] and technologies [256, 195, 189] to scaffold adult involvement in children's literacy, by **suggesting the need to design technology to scaffold a collective network of family supporters** rather than parents individually. Although at first blush this may be seen as intuitive, as there is a wealth of research on collective family involvement in education across cultures [199, 198, 154, 88], educational technologies and interventions continue to be designed to provide scaffolding or information to parents exclusively (e.g., often in the form of text message reminders) [256, 195, 219], including the wildly popular (though problematic [242]) ClassDojo platform [253].

In this dissertation, I identify how the various members of the collective educational networks described above play a variety of roles in supporting children's literacy by way of children's use of our literacy technology, Allô Alphabet. Prior research on the role that parents play in children's learning discusses how parents play multiple educational roles at different times, including "learning partners", "learning resource brokers", "collaborators", and more [67, 21]. Although we do find that parents in rural Ivorian contexts took on those roles, we find that these roles were distributed across the multiple family supporters in the child's life, changing based on the desires and availability of supporters, and requiring effort from these supporters to coordinate the distribution of these roles. As one example, we heard in Studies 2 and 3 that older siblings who had not typically played an instructional role with the child were explicitly asked to do so by the parents only after Allô Alphabet was introduced. In other families, we saw evidence that parents would actively recruit other family members to help with the French literacy lesson instructions (for instance, in a primarily Koulango speaking household), while other family members, who may have had more experience with technology, would be asked to help the child call and answer the IVR, or open the SMS (see Chapters 4 and 5). One naive implication of this finding would be for the designer of an ed tech system to assign a different role to each individual supporter in the family—as has been done with virtual agents in an intelligent tutoring system (e.g., [24]), with one person or agent playing the role of "expert", "motivator", or "mentor". However, in our studies, these roles were not fixed across supporters, but were instead fluidly taken on as circumstances changed. For example, the older sibling who was supporting the child with the phone functions might need to work at the *camp* for an extended period of time, and other family or household members would voluntarily step up (or be asked) to play that role. In some cases, no one was available who could for instance, monitor the child, and thus the child would use Allô Alphabet individually (if the family permitted it), or would not be able to use it at all if they did not (a tension discussed at length in Chapter 5

[149]).

These coordination challenges were exacerbated when systemic shocks occurred, as in school closures due to teacher strikes (described in Chapter 5) or due to COVID-19 (in Chapter 6). Now, in summer 2020, as much of the world grapples with how to continue education during the COVID-19 pandemic, questions around childcare and family-based learning with technology abound. Working parents, even those working from home, and even those whose children have access to devices and bandwidth to access digital learning content, find it difficult to sufficiently monitor and support their children. In some cases, wealthy American families are grouping into so-called "learning pods"[1] to provide small-group instruction for children by pooling resources. In the U.S. context, these COVID learning pods may only be available to those with sufficient wealth to afford the cost, but in other contexts, including what we saw in the rural Ivorian context, families have long relied on members of the extended family, household, and multi-household groups to provide distributed educational support. As we saw in this dissertation, when a learning technology is introduced, families negotiated to what extent they needed—or would be able—to continue to provide monitoring and support for children learning on a mobile device, given the other demands on their time.

As described in the preceding section, these collective support networks were accompanied by contested values, beliefs, and practices among the family supporters around literacy education and around learning with mobile devices. Despite nearly ubiquitous mobile phone ownership[2], families had conflicting, contested views over whether and how their children should use a phone, either for learning, or for other purposes. Some family supporters felt children could not be trusted to use the phone, either alone or supervised, while others were more comfortable allowing their children to use it for learning supervised or alone. This meant that in some cases, one caregiver would go to the training we provided at the start of the study, learn how to use the Allô Alphabet IVR, and bring the phone back to another caregiver, who forbade their child from using it for learning. These beliefs were also entangled with family members' values and beliefs around the feasibility or importance of children learning independently, with some prohibiting independent learning, others tolerating it, and others encouraging it. Although some of this may be explained by research on "parenting styles" (e.g., authoritative, authoritarian, permissive, and uninvolved) [155, 151, 209], our evidence for the collective nature of family educational support suggests that the frame of the "parent" in the research on "parenting styles" should be expanded to include the other family and household (and community) members involved in supporting the child's education, and should expand to include the process by which values, beliefs, and practices for children's education are contested, negotiated, and enacted by members of the family support network.

### 7.2.2 Adoption and use of voice-based mobile educational technology by rural families at home

Another primary set of findings across the four studies in this dissertation involves the way in which the adoption and use of voice-based, mobile educational technology at home is mediated by the collective family educational dynamics described in the previous section. In this section, I describe the ways in which rural families in low-literate contexts mediate children's use of a voice-based mobile literacy technology and the implications that this mediation has for adoption and use of (mobile, voice-based) educational technology at home more broadly. These findings

[1] https://www.businessinsider.com/pod-style-learning-unequal-addresses-key-issues-how-to-solve-2020-7

[2] 600/602 [99%] respondents and 715/777 [92%] respondents in Study 3 and 4, respectively, reported owning at least one phone in the family

contribute to HCI and ICTD research by identifying how low-literate families provide *educational intermediation* for children's use of interactive voice response (IVR) systems for education, and how family mobility in rural agricultural communities impacts family adoption of educational IVR.

### Intermediation of voice-based education technology

This dissertation advances prior research from the Information-Communication Technology for Development (ICTD) field on designing voice-based technologies for low-literate users [191, 192, 193, 235, 159, 4, 176, 127, 137, 177, 150, 164, 116] by **identifying how family members' intermediation of a voice-based system for children's literacy education creates unique challenges and opportunities** for using voice as a modality for literacy education in rural, multilingual contexts, as opposed to using such systems for information-seeking. With few exceptions, IVR systems have not been designed for educational purposes. As previously discussed in Chapter 2, IVR systems have primarily been designed for information-seeking [137, 177, 150, 177], or for community-building [164, 116] or social media [192, 234, 70]. Some recent work has, however, explored how IVR might be used to assess users' knowledge (e.g., of health information or government regulations) [193] and to provide health information training or second language instruction to adults [105, 227, 175], but IVR systems have not yet been studied for how they might be designed to support children's literacy education, and be supported by other family members, in turn.

In this dissertation, as children used an IVR explicitly designed to help them foster phonological awareness by teaching and assessing them on pre-literacy concepts, we uncover several ways that children's usage—and families' mediation of that usage—advances prior work. First, prior IVR systems were designed to be used individually, with an adult as the end user (e.g., [191, 192, 193, 235]). In our studies, while the child was intended to be the primary user, we see parents, siblings, and other supporters in the family (and the larger household and community) provide intermediation (cf. [204]) for children's use of the IVR (as described in detail in Chapters 5 and 6). In some cases these were synchronous, explicit instructions on how to use the IVR, or explicit "instrumental" support for the French literacy concepts being taught. In other cases, this intermediation was done asynchronously, with the adult calling the IVR on their own, modeling how to listen and respond, ending the call, and giving the phone back to the child to repeat it. Unlike Sambasivan's work on intermediation for information-seeking, where the intermediary could simply search and find the information and relay it to the beneficiary, our use case was for education, and thus the intermediary had to first learn how to use the affordances of the IVR paradigm themselves, then teach those skills to the child, all while helping support the child's active learning (cf. [124]) of the phonology skills—not simply telling them the answer as in information-seeking paradigms. In fact, in Uchidiuno et al.'s study on home-based use of a tablet for literacy learning, they found that when a child was learning on the tablet, their siblings would not offer help unless it was explicitly asked for [229]. In our case, perhaps because of the more publicly visible or more ubiquitous modality of phone-based interactions, we observed and heard about frequent spontaneous monitoring and help provision from siblings and other family members.

However, despite the widespread occurrence of such family-based intermediation and support for children's IVR usage, for many participants in our context, interactive voice response (IVR) was an unfamiliar paradigm, and was particularly unfamiliar for educational purposes. That is to say, one of our desiderata that arose out of Study 1 was to design a platform on a hardware device (i.e., a basic mobile phone) that would be ubiquitous and thus, familiar in the context.

Given the ubiquity of mobile devices in families across multiple studies in 8 villages, including the presence of the same brand of phone owned by many families, this design guideline was borne out. Our desiderata for the application (as opposed to the device), however, was that it would be accessible by low-literate users, and thus, we chose to use a voice-based system, inspired by the uptake of IVR systems in other contexts and domains (e.g., [191, 192, 193, 235]). Given the challenges we observed with many families with understanding how to use the IVR (e.g., with calling the number, waiting for the IVR to call them back, answer, press touchtone buttons in response to pre-recorded, automated verbal instructions, etc), it seems that knowledge of the affordances of IVR were not as widespread. In Study 4, we posed a survey item asking about experience with IVR, and found that nearly 20% (152/777) of respondents *had* previously used an IVR, but when we asked this question in interviews, it seemed that this was mostly for adding credits to a telecom account by calling one of the mobile network operators (MNOs). Participants faced challenges in using an IVR for education, and particularly for supporting their child's use of IVR in ways that were pedagogically valuable, and aligned with the caregiver's educational ideologies—as some caregivers wanted to allow the child to learn independently, while others wanted more active supervision, monitoring, or support from adults (Chapter 5).

Moreover, the fundamental design of interactive voice response systems—playing pre-recorded messages and waiting for a touchtone input—may be challenging for collective or intermediated use. We saw this across many observations of the IVR use at home, where one primary user (the child) tried to listen to the instructions, while one or more other family supporters was also listening in and trying to offer feedback or suggestions, while the message repeated. In some cases, the environment where the child was using the IVR was quite noisy, with younger children, motorcycles, and other environmental noises, despite the best efforts of the caregiver to provide a quiet place for learning. In addition, although the basic phones had the option for a hands-free speaker, many participants did not voluntarily turn it on, despite knowing about that feature. Compounding all of these challenges is the bilingual nature of our contexts, where many participants spoke some French, but the majority of participants reported speaking a language other than French at home (such as Attié, Koulango, Dioula, and others). All of this suggests that designers of educational voice-based systems should consider how these collective intermediation approaches affect how children—and their family supporters—are able to engage with a voice-based educational technology.

### Family co-location as a factor in educational technology used outside of school

Next, this dissertation advances prior research on children's use of educational technology at home with their families [185, 220, 229, 152, 82], by finding that **children's opportunity to use mobile devices for learning is impacted by family members' mobility between the village and the cocoa farm camps**. We find that adults' desire for supervision is complicated by this mobility, necessitating that children learn independently or quasi-independently, perhaps before they are able to effectively self-regulate their learning. Prior literature suggests that self-regulated learning with technology is a learning goal of caregivers [229, 185, 220], but children may not be provided with sufficient scaffolding to develop this self-regulation on their own.

First, as we saw across multiple studies, parents' and caregivers' concerns about their children's access to mobile devices were primarily (though not exclusively) centered around concerns for the safety and security of the device and the physical safety of their 8-12 year old child having a mobile device in their possession. These concerns were not unwarranted—in Study 4, we found that nearly 5% of participants had their phones lost, stolen, or irreparably damaged. To address this concern (and other concerns about children using the credits or airtime, or using the

phone for purposes other than learning), caregivers often kept the mobile devices we provided them on their person, even when they traveled. Given the nature of the collective involvement in learning, this meant that in some cases, adults other than the parents were the ones who kept the phone, limiting children's access to the device if they did not co-habitate with that other family supporter. In other cases, even when the child lived with the adult who kept the phone, the adult would often travel to the *camp* for extended periods of time, taking the phone with them, while leaving the child behind (or taking the child, while leaving the phone), as seen repeatedly in Study 3 and 4. Thus, while children participating in school programs around the world are given a device for learning, ostensibly to allow them to learn online without needing to use the family device [194, 55], our results suggest that even when children are provided with their own device for a learning intervention, the social dimensions of adults' desire for control and supervision of children's use presents obstacles to children's sustained access to learning technologies at home.

In the rural Ivorian context, the farm plays a large role in families' lives, as family members who work on cocoa farms (often including children [201], as we saw in Studies 3 and 4) often live there for days or a week at a time, impacting their co-location with the child using Allô Alphabet. The evidence of the impact of children's cocoa farming activities on their use of our mobile educational technology was mixed in this dissertation. In Study 3, we saw a negative effect of children's agricultural work activities on their system usage (i.e., number of calls to Allô Alphabet), with a positive effect of domestic work activities on calling. We thus hypothesized that children who worked at home on domestic tasks were more likely to be co-located with a caregiver who controlled access to the phone, while those working on the farm would travel outside the village, and either not have access to the device or lack sufficient cell signal at the *camp*. However, in Study 4 (Chapter 6), we saw different results. Surprisingly, we saw a positive effect of working on hazardous cocoa activities (e.g., burning or clearing trees, or spraying insecticides or chemicals) on the number of calls made to the IVR and (though it was marginally significant) a negative effect of working on *non*-hazardous activities on calling the IVR. One hypothesis for this difference might be that children who are doing more hazardous cocoa activities are given more responsibility by adults—both in their work activities, and perhaps, in their learning with the mobile device. Lending support to this hypothesis, we saw in our qualitative data that, over several months of our two deployments, family supporters and children negotiated various levels of autonomy over children's ability to independently use the mobile device and access the Allô Alphabet platform in Study 3. In some cases, this independent use was out of necessity, as no adult supporter was available to help or monitor, while in others, the adults expressly wanted the child to learn how to learn independently. However this independent learning requires that children have sufficiently developed meta-cognitive abilities[3] to self-regulate their own learning, by calling the IVR on their own, and persisting in using the system to learn without an adult reminding them to call. As the children in our studies comprised a wide range of ages, from 6 to 17 years old (mean=11 for Study 3 and 10.8 for Study 4), these children's meta-cognitive ability to self-regulate their own learning may have differed widely, potentially impacting their consistent use of Allô Alphabet to learn.

[3]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., [58, 83, 206]). However, the extent to which children are motivated to set learning goals varies widely (and the extent to which they are able to, given their meta-cognitive development), 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., [27, 202, 58]).

## 7.3 Design Implications

### 7.3.1 Designing technology for family literacy support

First, we suggest that designers of family educational technologies should consider how to design scaffolds aligned with families' existing literacy activities. For instance, as we saw in our findings, many family members are providing a variety of educational support (from advice, motivation, encouragement, resources, to explicit instructional help and reading), but these may not occur in moments when it is most needed by the children. Thus, a mobile literacy system might provide suggestions for specific motivational or dispositional messages (e.g., about the importance of productive failure [111] or growth mindset [74]—both of which we heard examples of from participants in the study) at times when the system determines that children are struggling with mastering a concept. While some systems [256, 195, 106, 189] have sent automated messages with tips to parents, personalized by children's performance on school assessments [68], these systems have not designed the messages to be personalized based on the particular content the students need help with, at the moment they need that help, nor are those messages personalized for the particular cultural background of families, or for their preferred style of educational involvement (e.g., given the contested preferences of members of family support collectives).

This may take the form of culturally-aligned lesson items (cf. [131, 85]), such as teaching words as part of a narrative drawn from folk stories [11] or support for intergenerational story-telling [69]. However, given the cultural differences between many educational technology designers for low-resource contexts, and the culture those technologies are intended to be used in (as with our Allô Alphabet system), it is critical to engage local curriculum designers in creating this content. Or, ideally, as culture is not monolithic within a single country or community [32, 158, 163] a voice-based system might allow family members to record their own messages (e.g., instructional, motivational, etc.) to provide this content in a way that is most appropriate for their unique culture and family. For family-based literacy systems for low-literate adults, the system might suggest specific words, letters, or phonemes for adults to use in the stories they are already telling their children (of which we heard several examples of from families). Alternatively, this might also take the form of suggesting that adult caregivers suggest locally-relevant uses for their children's burgeoning literacy abilities—as in the grocery lists mentioned by one Ivorian mother—applications that may be of immediate practical use to the family and which could provide authentic motivation for children.

Given what we heard from families about the games their children play, designers might also consider ways of engaging multiple children in literacy games or activities, perhaps by having the system pair students of different ages or literacy levels to leverage the benefits of peer or near-peer supportive interactions with older siblings [224, 143, 229, 154, 88]. Alternatively, given the desire we saw from some parents to learn to read in French themselves, designers of literacy systems might allow parents to play a supportive role in such games (what Barron et al. calls the "collaborator" or even "co-learner" roles [21, 67]), where they are learning the concepts while playing with their children, but designed in such a way to spare them the potential embarrassment or "face-threat" of learning the same lessons as their children (see [146] for more specific design suggestions).

### 7.3.2 Designing for negotiated autonomy in technology-enhanced family learning

In Study 1 and 2, we found that caregivers in our context wanted to provide hands-on, explicit support for literacy (cf. [136, 212]) and wanted to control children's use of mobile devices.

After 15 weeks of deploying Allô Alphabet in Study 3, 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 [27, 202] in parent-child relationships, as well as prior research in children's self-regulated learning [206]. 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., [58, 83, 206]). However, the extent to which children are motivated to set learning goals varies widely (and the extent to which they are able to, given their meta-cognitive development), 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., [27, 202, 58]). In our studies, we found evidence (as reported by adults) that children increasingly desired autonomy and control over their learning with technology, and they negotiate this desire in tension with their caregivers' concerns around unsupervised use of technology, as well as caregivers' goals for their children to become autonomous learners. However, the primary source of this evidence was in qualitative interviews in Studies 2 and 3. In Study 4, we did see quantitative evidence from call log data that many users had someone (whether an adult in the family or community or the child themselves) who accessed the adult supporter system throughout Study 4. However, it is not clear how this access translated into the actual support described by the adults in Study 3, and it still may be the case that although some adults were accessing information consistently, they were fading their explicit, verbal support over time.

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 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 [127], 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 adults who control or monitor 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 (as in [206]). While this practice has been adopted in other contexts, there remain open design questions as to how best to design meta-cognitive 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 fostering children's self-regulated learning.

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 meta-cognitive 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 [169, 5] (which may

be prevalent in this context, given that we heard some adults discouraging their children from asking for help). Thus, future educational technologies for families might provide alerts to adult supporters when it appears that children are "wheel-spinning" [25] without making progress, or provide support akin to the "invisible hand-raising" suggested by Holstein et al. [96], perhaps delivered via SMS messages or automated voice calls, depending on adult literacy levels.

### 7.3.3 Power and politics in educational technology research

Designers of educational technologies make choices (explicitly or implicitly) about what is important for learners to learn and why and how they should learn it. While technologies for learning may have positive impacts on learners' acquisition of knowledge, a narrow focus on gains in learning misses the bigger picture—that learning is a social and cultural process embedded in socio-political contexts that shape, and are shaped by, educational institutions and technologies. These socio-political legacies may have far wider and deeper impacts on learners and society than the incremental learning gains of an effective educational technology.

In Francophone West Africa, literacy education has long been a tool of the colonial project [37, 32, 14]. Now, as data-driven technologies designed in the Global North are exported and deployed across the Global South, we risk reproducing these legacies through "algorithmic colonization" [29]. In human-computer interaction (HCI) research, Irani et al., in their work on postcolonial computing, have argued for research practices that attend to the ways in which the power relations within and between groups of stakeholders are enacted in design practices [100]. More recently, Sasha Costanza-Chock, in her book "*Design Justice: Community-Led Practices to Build the World We Need*", writes that design justice is a "framework for analysis of how design distributes benefits and burdens between various groups of people" [52]. This process involves interrogating how certain values are encoded into designed systems and how these design choices reflect and reproduce power within a matrix of domination[4]. Costanza-Chock describes this phenomena primarily in the US context, where she describes how this entails engaging with the legacy of white supremacy, patriarchy, and settler colonialism, along with forces of ableism and cis heteronormativity.

While this framework does not neatly map onto what such design justice may mean for Global North researchers conducting research in the Global South, such as myself, it does provide a useful framework with which to widen the lens of the design implications described in this thesis. As Global North researchers working in the Global South[5], given the legacy of neocolonialism in education [14], French literacy [32], technology [28], and research more broadly [218], it is critical that we consider the ways in which educational technologies—and our processes for researching, designing, and deploying those technologies—may reproduce or amplify existing inequitable power relations. Costanza-Chock's design justice is not only about the design of a particular technology, but also includes interrogating how research studies are designed, and, at a higher level, how research *infrastructures* (e.g., funding models, research processes, etc) are designed, which give rise to research studies, which may in turn give rise to technologies that systematically reproduce or reify neocolonialist power relations. In other words, while the previous subsections have discussed implications for designing learning technologies, this subsection discusses implications for the design of our research processes more broadly.

[4]Patricia Hill Collins' "matrix of domination," is a model that "helps us think about how power, oppression, resistance, privilege, penalties, benefits, and harms are systematically distributed" [48, 51].

[5]As Wong-Villacres et al. point out, the binary of North/South is artificial, as for example, Mexico is in North America, but is considered to be in the Global South. However, the binary remains in use in development discourse. See [248] for a more extensive discussion.

### Language and literacy educational technologies

Educational technologies, particularly literacy technologies, are situated in the socio-political milieu of the languages (and by extension, cultures), which are valued by society and welcomed at school, as suggested by prior work on the use of African-American English (AAE) in American public schools [94, 39, 214] and prior work in multilingualism in urban Ghana [107] (among many others). French literacy instruction has long been a tool of colonization in Africa [37] and in Francophone West Africa in particular [32], as in other former colonial contexts. As Eyamba Bokamba points out, the French colonial project has worked for generations to assimilate children in Francophone West African contexts into learning French, despite sustained advocacy for instruction in local languages from educators and linguists in the region [32, 14]. In Côte d'Ivoire, after decades of advocacy for bilingual instruction, the Ivorian Ministry of Education (MENETFP) implemented the "Integrated School Project" (PEI) for bilingual teaching and learning in a local language in early grades in 2001, although implementation has not been widespread [138, 47, 80]. Further, in communities with a large set of mother tongues, as in many communities in rural Côte d'Ivoire, the selection of *which* local language is used in such bilingual instruction has political implications[6], and choosing one local language in which to teach in the PEI schools, out of, for instance, the 23 local languages in the 8 communities in Study 4 may reproduce existing patterns of marginalization of certain ethno-linguistic groups in the larger political and educational process. In the rural Ivorian context this research was conducted in, this marginalization has resulted in under-investment in resources for ethnic minority and migrant communities [201].

The goal of the research program discussed in this dissertation was to improve Ivorian children's French literacy. The Ivorian Ministry of Education pitched the focus of this project to the NGO that funded the work, in collaboration with an ed tech start-up, Eneza Education (based in Kenya with an office in Abidjan). Technologies that teach literacy have the potential to either further reify the majority linguistic group's dominance over literacy education [94, 181], or they could demonstrate to local language speakers that their language has value in the development of multiple literacies in a multilingual context (see [31] for a larger discussion of the power dynamics in language technologies). Although we found in our qualitative interviews in Study 1 and 2 that many rural Ivorian families did want their children learning French, given that schools were teaching in French and given its role in Ivorian economic life, other families emphasized the importance of learning and using local languages in the village context, though these were the minority in our sample. This is a critical point, however. That is, if researchers' design processes privilege the desires of the majority of participants (in this example, for teaching French literacy) over the perspectives of a minority of participants (e.g., families who want their children to develop local language skills), we risk reproducing the same inter- and intra-community power dynamics that have historically marginalized families from minoritized groups[7]. It is also worth nothing that these viewpoints are not necessarily mutually exclusive and may be held by the same members of the community. Rural Ivorian families might want their children developing French literacy in order to continue participating in schooling and the national economy while also maintaining and developing their local language proficiency.

In Study 1, we elicited families' beliefs, goals, and practices for literacy education, and desires

[6] In 1976, the president of the Ivorian National Assembly, Philippe Yacé, argued in favor of French as the official language of instruction, and assigned the task of choosing "4 or 5" languages to use as the medium of instruction to researchers at the University of Abidjan [32].

[7] See Cooke and Kothari for a more extensive discussion of navigating contested desires in participatory design for development [50].

and concerns for children learning with technology. Those findings shaped the way the French literacy concepts were taught and the way instructional system was designed. However, the fundamental design goals of teaching French literacy using technology were determined prior to our qualitative research with families. As David Mosse points out in *Participation: The New Tyranny* [166, 50], despite a rhetorical turn towards participatory research in international development, the organizational incentives and funding structure of international development are not aligned with the sort of radical empowerment that might lead to fundamental transformations in education and civic life (cf. [81]). According to Mosse, and more recently, others like Mona Sloane et al. [217], the rhetoric of participation is often deployed to ratify or legitimize design decisions made prior to input from the community. For the dissertation research, although local community members participated in the design by giving input on the focus of the instruction and nature of learning with technology, the goal of teaching French literacy with technology remained unchanged. Moreover, the multiplicity of contested interests, cultures, and sub-communities that are contained within the rhetorical move of "community"-driven design [163, 166, 50, 217] are likely to shape those design decisions, and in ways that may reinforce and reproduce existing inequitable power structures both *between* community members and researchers and *within* local communities. In Côte d'Ivoire, community divisions along socio-economic and ethno-linguistic lines have historically been exploited by Ivorian leaders for political purposes [254]. In this dissertation research, those existing community power dynamics may have led, for instance, to our research team being more likely to recruit families who spoke French, or in the case of families who spoke no French, to recruit those who spoke one of the predominant local languages that our research assistants spoke. This may have contributed to systematic gaps in our understanding of the needs and desires of families from already marginalized ethno-linguistic groups. Thus, despite the initial goal of the research originating with local actors (i.e., Ivorian, albeit from the state government and local technology sector), the desires of the state in the form of the Ivorian Ministry of Education, as translated through what was seen as technically feasible by an ed tech startup based in the urban center of Abidjan, may not have been well-aligned with the desires of members of the rural communities in which we worked, and may have inadvertently led to retrenching existing power structures. In multilingual contexts where families' language and culture may not be aligned with that of the teachers and schools—or where parents and family members may already feel alienated from engaging with teachers and schools (cf. [249, 252, 250, 94, 39])—educational language technologies (such as Allô Alphabet) that are designed to be aligned with the language used in schools may further alienate parents and lead to a lack of adoption and use at home.

To make this concrete, **designers of educational language and literacy technologies should, at a minimum, support multilingualism in their technologies intended to be used in multilingual contexts**. This may take the form of including both the official national language and local language(s) in the instructional content. In the design of Allô Alphabet, we incorporated phonemes shared between French and the majority local language (Attié) in the curriculum, and we included several instructional messages recorded in 4 local languages. A more robust version of this would provide users (and their family supporters) with control over which languages are used by the system and for what purposes (e.g., instructional content, explanatory or informational messages, support content for family members, etc). In our studies, we found that only 28% of participants reported speaking French at home, but 21% (255/1203) reported speaking multiple languages at home, making it even more challenging, but necessary, to accommodate multilingual users in a single language technology. Research is emerging in natural language processing (NLP) on developing corpora for local African languages [57, 73, 173, 162], and for supporting code-switching [216] and multilingualism in language

technology [238, 59], but this research has yet to achieve maturity.

More broadly, **designers of literacy technologies should work to understand the political dimensions of the socio-linguistic context in which they intend to deploy such technologies, considering how such technology may towards or away from marginalized communities** [31, 108]. This may involve drawing on theories and methods from design justice, postcolonial computing, or participatory design. Specifically, such work might involve recruiting members of historically marginalized populations in the deployment context early in the research process and giving them meaningful power as partners (compensated appropriately) to shape the research goals and questions[8]. However, it is critical to carefully consider how to do this in ways that are not exploitative or extractive and do not expose them to undue risk through this process, considering the power dynamics between researchers (often from well-funded international NGOs) and members of the communities (cf. [217]). This may also involve working to articulate shared values across groups of stakeholders, such as families, teachers and school leaders, community leaders, national education policymakers, and international foundations, rather than taking the goals from one such group (e.g., national education leaders) and using those to motivate requirements elicitation from other groups (e.g., families) for a design to support that goal (cf. [112]). However, given the power dynamics between groups of stakeholders, it may not be possible to reach a consensus around shared values or goals (e.g., designing for "dissensus" [117]). Further, by the time that stakeholders from impacted communities—particularly marginalized communities—are involved in the process of designing technology, their input may be tokenistic, used to legitimize decisions already made earlier, or it may be too late to reverse the harm (or to reverse the precedent that such designs establish) [50, 217, 147]. In many such cases, it may be better to not continue the research or design at all—and researchers and ed tech designers should be prepared to discontinue research and design in cases where continuing it may lead to further harm for already marginalized communities ([20, 23]). This suggests that our research communities' **grant funding and reviewing approaches should better value and support research that involves community members as meaningful partners early and often throughout the research**. This may entail valuing grants that include members of potentially impacted communities as co-authors and co-PIs (compensated for their time), involving members of potentially impacted communities as compensated reviewers of grants, and more (cf. [13, 112, 30]).

### Techno-solutionist ideologies in education technology

The power dynamics and political contexts described above may not only impact the nature of an education technology designed, but may also shape the meta-decision that technology is (or should be) the appropriate form of an intervention for educational challenges. During the COVID-19 pandemic, New York's Governor Cuomo announced a plan to work with the Bill and Melinda Gates Foundation to "reimagine education" [9], citing the pandemic lockdown as an accelerant of a shift to a future of remote, private-sector-enabled, learning. As Naomi Klein and others [245, 2] have argued, this line of thinking represents a new instance of "disaster capitalism", using a crisis to drive adoption of capitalist reforms [123]. In education, the movement towards technological solutions for public educational challenges has predated the current crisis [56, 210, 243, 139]. While it may be the case that some children may learn more from

[8]See ongoing work in the health research field to develop standards and research processes for "community-engaged research" [13].

[9]https://www.washingtonpost.com/education/2020/05/06/cuomo-questions-why-school-buildings-still-exist-says-new-york-will-work-with-bill-gates-reimagine-education/

using education technology, the drive towards technologization of learning may have larger (e.g., society-scale) and longer-term consequences for education systems, suggesting that researchers in education technology-adjacent fields, designers of ed tech, and members of foundations and public education agencies that enable this research should carefully consider the implications of choosing technology as the solution to complex social issues.

This movement towards technologization of learning is part of a larger ideology of "techno-solutionism" [161, 165]—the belief that technology can solve deep-seated, complex social issues—endemic in the field of education technology. This manifests in the belief of some education technology evangelists that simply "giving children laptops and getting out of their way" [240] will be sufficient to improve education. Although the naivete of this techno-solutionist viewpoint is easy to identify in such a reductive form in, for instance, the much-critiqued One Laptop Per Child (OLPC) project [240, 8], nearly a decade after OLPC, the influential and well-funded Global XPrize called for "teams from around the world to develop open source and scalable software that will enable children in developing countries to teach themselves basic reading." [1]. This call perpetuates the techno-solutionist ideology of OLPC in the mistaken belief that technology on its own can solve complex social issues such as children's education. This belief in technology as a "magic bullet" solution for complex social issues recurs in our field in subtle ways, from the research and design choices made throughout the educational technology design and deployment lifecycle, to calls for proposals from foundations that fund this research and development (as in this dissertation research), to the goals of public sector education policymakers that shape those calls for proposals (as in the Ivorian Ministry of Education).

In reality, simply providing access to technology is insufficient for achieving equity and justice in education, as Roderic Crooks found with student technology leaders who were deputized to support the deployment of iPads in South Los Angeles [55] and as Steve Jackson found in technology repair communities [102], among other examples. In this dissertation, we saw evidence for the critical role played by this social infrastructure in the form of the family and community members who helped explain how to use the mobile phones, mediated children's access to the phones, and who helped fix issues when they arose. We saw family members provide sociotechnical support for children's phone use using their own time and resources (e.g., providing their own phone chargers if one of the study phone chargers broke). In addition, in Study 4, overall usage rates were impacted due to technical issues with the devices (e.g., users accidentally "blacklisting" the IVR number, getting locked out of the SIM card, etc), and so we recruited local Ivorian teachers from the communities to provide technical troubleshooting support. We paid the teachers for their time, and our Ivorian research colleagues provided training for the teachers on how to do such troubleshooting. However, this social infrastructure necessary to support the ongoing usage of the educational technology belies the notion that one can simply introduce technology and expect "children... to teach themselves" (as seen in the 2018 XPRIZE call for proposals [1]). Without the intervention from our research group[10] in paying for teachers to troubleshoot (or, as in the issue with SIM card registration in Study 3, obtaining a waiver of the national SIM registration law prior to Study 4), families without sufficient time, resources, or capacity to fix technical issues with their children's devices would have borne these costs entirely on their own and may have been prevented from successfully using the system. Thus, education technology researchers and designers should work to **understand and design for the sociotechnical infrastructure that mediates and enables the use and impact of the ed tech, as well as develop support for ongoing adoption and use of ed tech**

[10]Although Eneza Education did provide substantial resources, personnel, and time to supporting ongoing technical issues, including several weeks of in-person troubleshooting in the villages.

**by the community**.

The ideology of techno-solutionism in ed tech not only manifests in that hyper-focus on the role of technology by bracketing out the rest of the surrounding social infrastructure supporting its use (akin to what Selbst et al. have referred to as a "framing trap" in algorithmic systems [208]), but it may also manifest as a mis-specification of goals. That is, technology may be proposed as a solution to address fundamentally social issues which technology may be ill-equipped to address (i.e., a "solutionist trap" of algorithmic design [208]). Now, during the COVID-19 pandemic, ed tech evangelists in the US have seized upon the pandemic as an opportunity to proffer their technology of choice as the solution to continuing children's learning. Global venture funding for ed tech reached $4.1 billion between January and July 2020, $1.5 billion more than the same period in 2019[11]. As one example of the techno-solutionism of this moment, schools look to plagiarism detection software (e.g., Turnitin.com) and proctoring software (e.g., ProctorU, Proctorio, and others with similarly ominous names), which frame complex social challenges of academic integrity as technical challenges requiring technical solutions, among numerous other examples [245, 222].

In this dissertation, this techno-solutionist ideology manifested in the *a priori* decision by the Ivorian Ministry of Education, the Jacobs Foundation, and Eneza Education to call for an educational technology to help address gaps in childhood literacy. As with other social challenges in education (e.g., plagiarism, classroom management [242], and school security [26, 84], among others), the *a priori* choice of a technology as the solution for early literacy in rural Côte d'Ivoire already frames the problem in ways that are legible to a technological solution. In other words, the design space of potential interventions to help address gaps in early French literacy was already constrained to interventions that could be deployed with a technology, before engaging with stakeholders from potentially communities, asking families in these contexts what they needed or wanted. In fact, when we conducted such needs-finding interviews in Study 1, we heard evidence that families wanted updated textbooks in schools, storybooks and workbooks provided to families, better training for teachers, funding for school infrastructure and families' school supplies, financial support for private tutors, additional farm labor (so children who needed to work on family farms (as described in [201]) could attend school more regularly), or training for parental or family literacy interventions.

In fact, in Côte d'Ivoire specifically, state-level investment in educational technology has had a politically charged history. In 1971, the Ivorian Minister of Education, along with the Ivorian president, launched an initiative to provide access to educational television programs (PETV) for schools without enough teachers, "intended to reach every rural hamlet by the 1980s" [254]. This program was met with widespread resistance from parents, teachers, and teachers' associations, who saw the national-level investment in educational television as a political move intended 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 [254]. Organized teachers' associations continue to wield political power in Côte d'Ivoire to this day, as we saw in the 2-month long national teacher strike during Study 3. It is in this socio-political and historical context that our research was situated, with our educational technology offering an opportunity for students to continue learning during the teacher strike, by way of international foundation investment (through partnerships with the Ivorian Ministry of Education) in private a educational technology company.

Enthusiasm for private sector education technology in public education is widespread, and part of the larger neoliberal tendency towards privatization of public goods and services [19, 157].

[11] https://news.crunchbase.com/news/back-to-school-edtech-vc-funding-reaches-4-1b-so-far-this-year/

Public education has seen a similar enthusiasm for privatization via educational technology, threatening public control over education as power over educational decision-making shifts into the hands of corporations and philanthro-capitalists who fund ed tech research and development [244, 157]. This tension between public resources provided by the state and the enactment of a parallel service delivery platform from the private sector is a broader issue in international development research [163, 50]. Perhaps, in some cases, NGO funding for the educational technology research would be better spent investing in public education, rather than investing in private ed tech startups, regardless of their location of origin[12].

So what might be done about this? As with the previous discussion of power relations in literacy education, the issues raised here are endemic to the field, and the implications are not solely for the design of education technologies, but they also implicate the research processes and funding models that undergird that technology research and design. Existing learning science and ed tech funding sources inform the goals, contexts, and conditions in which learning scientists do their work, which shapes the directions of that research. Findings from this research, instantiated in particular models, theories, and tools, then make their way into ed tech practice—including by researchers embedded in practice (e.g., self-described "learning engineers" [205]). Eventually, successful learning science projects implement their technology at scale, which then shapes the behaviors of other participants in this ecosystem—schools, teachers, policymakers, and peer researchers. Those success stories are then fed back into what becomes valued as legitimate science—and what becomes seen as necessary requirements for both government and philanthropic funding in the next cycle. The result is a feedback loop that is constantly informing, shaping, and reinforcing a set of values and methods among learning scientists. Opportunities for a drastic rethinking of the techno-solutionist goals of existing research lines are rare and risky, particularly for graduate students working on foundation-funded research.

This suggests that **the granting agencies that fund the research underlying educational technologies (e.g., national funding agencies as well as foundations) should explicitly value (i.e., explicitly call for, look for in reviews, and fund) research that considers and engages with the larger social context** around the use of educational technologies. This may involve including budget items for paying for community mobilizers (e.g., community members who may be available to support—or rally support—for technology adoption and use, such as in [164]), funding for troubleshooting and technology upkeep and repair, and funding for ongoing trainings and information sessions for community members, among other possible items. This reframing may also involve funding research that attends to the historical power relations and political dimensions of the local educational context prior to choosing to design or propose a technology to "solve" social problems. In some ways, this is a complementary call to the implications of the previous subsection. At the very least this suggests that **members of impacted communities should be consulted (at least) and ideally involved as meaningful partners in designing the calls for research and investment in educational interventions, to align those interventions (be they technological or not) with their own interests**. In order to take seriously the implications of power and politics in local contexts, researchers and technology designers should avoid privileging technical solutions over complex social issues, which may require research grant agencies to develop incentives in their calls aligned with those values. Moreover, this suggests that **researchers (and reviewers) in our field should value critical research that articulates problems and issues and attends to the messy realities of socio-political context over research**

[12]Eneza Education, despite being an African start-up, is not exempt from the larger problems of the privatization of public education any more than US-based ed tech startups are exempt from similar concerns for privatization of public education in the US

**that leaps to neat solutions for complex social phenomena**. As researchers in the field, as people who review conference papers and journal articles, who help chair conferences and edit journals, and who review grant proposals and who may be asked to give input to foundations or perhaps even to venture capitalists looking to invest in ed tech start-ups, we have the opportunity to shape the types of research that is valued and supported, towards research that attends to the messy complexities of social context and the relations of power and politics (and is skeptical of reductive techno-solutionist ideologies), and that works towards more just and equitable relations.

## 7.4 Limitations

First, as discussed above, my perspective on this research is limited as a cis white American male working in a Francophone West African context. Although we worked closely with our Ivorian research collaborators to analyze the data from an Ivorian perspective, there were likely cultural nuances and interpretations that I missed, particularly as I was learning French over the course of this research, and thus relied heavily on translations from our Ivorian collaborators (Fabrice Tanoh, Hermann Akpe, Axel Blahoua Seri, Adji Yves, Danielle Kaplan, and others) for the semi-structured interviews. In addition, the majority of the interviews and design sessions were conducted with adults and not with the children themselves. While we did conduct several storyboard design sessions with children, piloted some prototype designs with children, and children were involved in all of the home observations, the primary participants in the interviews were adult caregivers, not the children. The survey items used in Study 3 and 4, while co-created with and validated by our Ivorian collaborators, may have been interpreted by the respondents differently than intended. Specifically, several of the questions around the caregivers' role in the child's education, including whether they were the "primary person responsible for the education of the child" may have been interpreted differently than intended.

Finally, and perhaps of most interest for the learning scientists reading this, although both Study 3 and 4 were designed to be randomized controlled trials of the efficacy of the intervention in improving assessed learning outcomes, the endline assessment in Study 3 was canceled due to the substantial technical issues with SIM registration leading to underpowered participation, and in Study 4, the planned endline assessment has been delayed until October 2020 due to school closures for COVID-19. Thus, this study does not include a controlled assessment of the learning gains of children who used Allô Alphabet compared with those who did not. See the pre-registration[13] for more detail on the planned endline assessment for fall 2020.

## 7.5 Conclusion

This dissertation describes the process and results of an iterative, longitudinal, design-based research program to (1) understand rural Ivorian families' literacy practices; (2) design a technology to support those practices and foster children's French literacy foundations using low-cost feature phones; and (3) understand how families adopted and used that voice-based educational technology, Allô Alphabet, using multiple deployments of Allô Alphabet as a probe to uncover rural Ivorian families' beliefs and practices around supporting children's learning with educational technologies at home. This thesis contributes to research in the fields of the learning sciences, human-computer interaction (HCI), and information-communication technology for

[13] https://osf.io/n53w8/?view_only=6055dd7d46394a4c821f9e6015e1bd7c

development (ICTD), as well as to policy and practitioners in education, education technology, and international development.

Appendix A

# Appendix A: Allô Alphabet System Design Diagrams

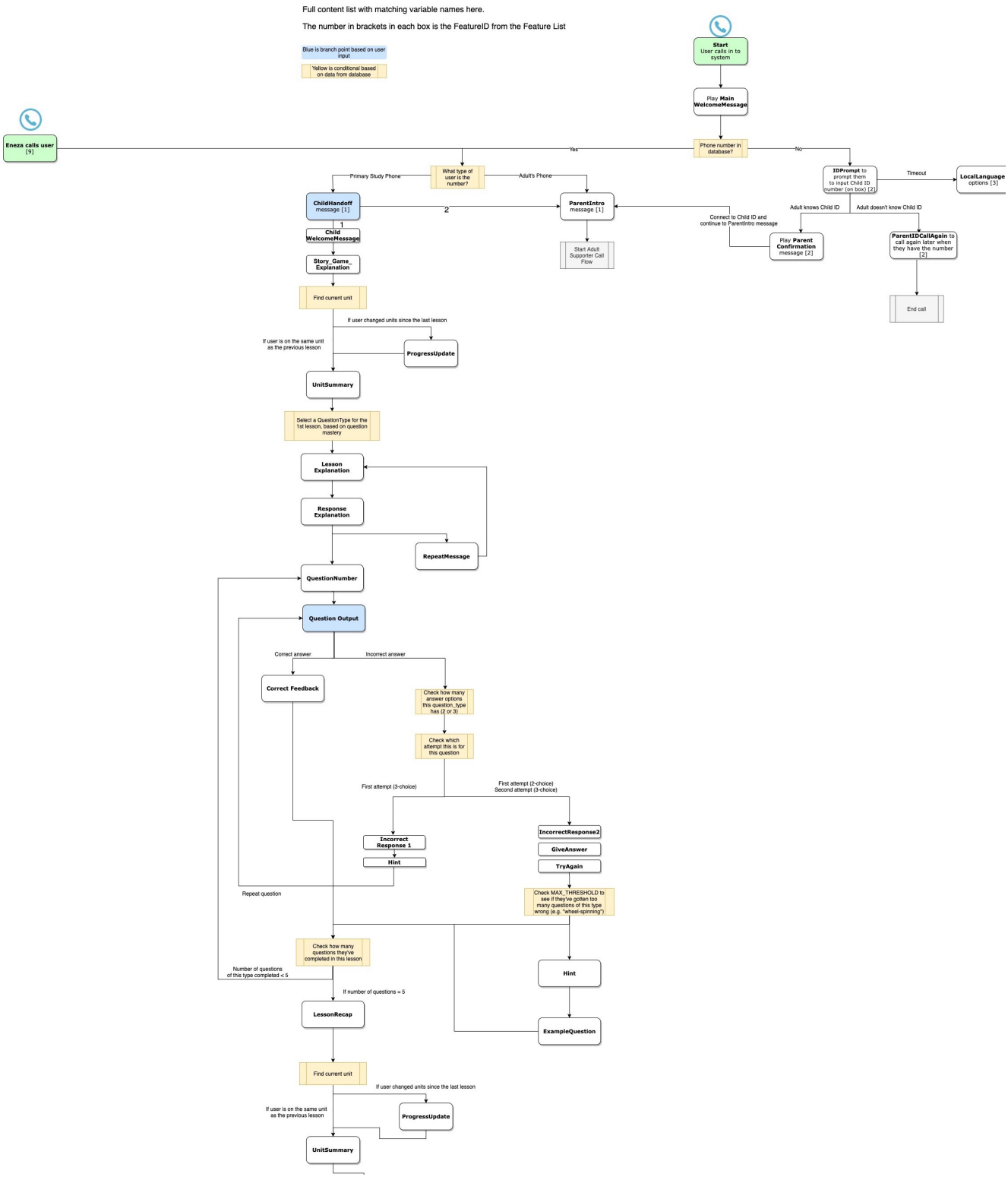


Figure A-1: Allô Alphabet Primary System Design Diagram, part 1

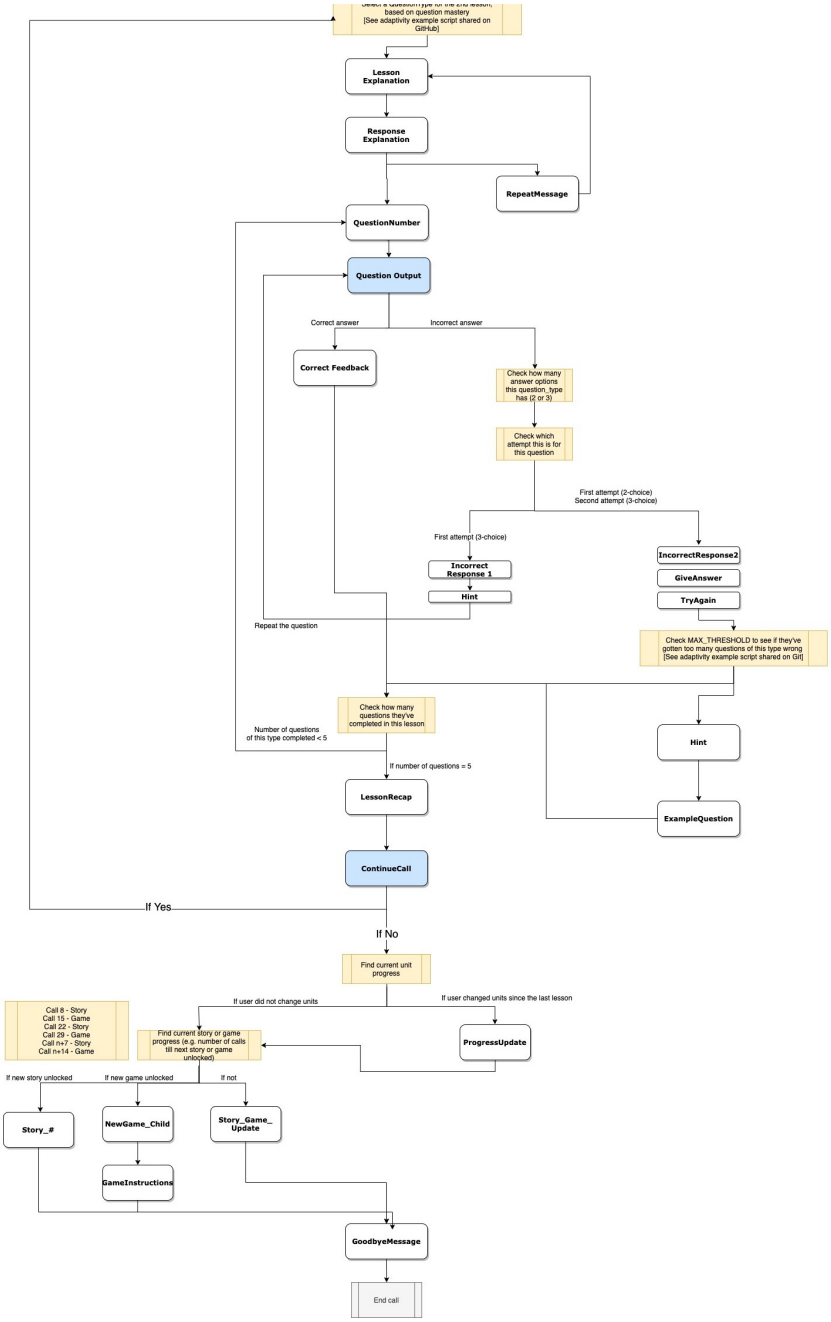


Figure A-2: Allô Alphabet Primary System Design Diagram, part 2

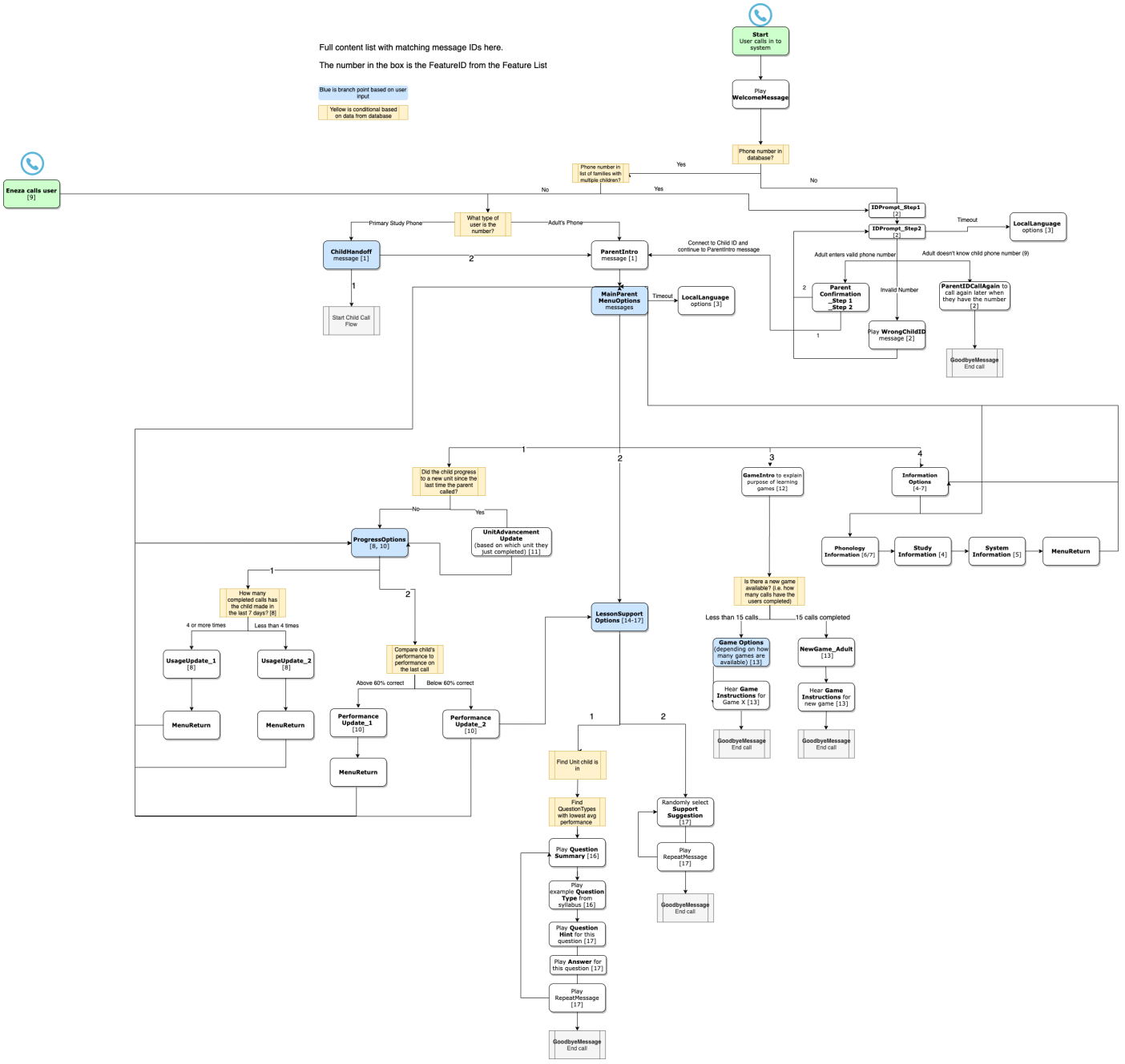


Figure A-3: Allô Alphabet Adult Supporter System Design Diagram

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