Thesis Proposal

Understanding and Scaffolding Parental Support for Children’s Early Literacy in Rural Communities in Côte d’Ivoire

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Abstract

Parents and adult caregivers play crucial roles in supporting children’s literacy at home, but in low-resource, developing contexts, parents may lack sufficient literacy to provide the most effective support. As mobile devices become increasingly ubiquitous across developing regions, such as Côte d’Ivoire, they have the potential to augment children’s home literacy environments. However, existing approaches have primarily been designed for children as the sole users, without designing to support parental engagement, particularly for low-literate adults.

In the first stages of this thesis, I have conducted two studies as part of a design-based research process to understand how low-literate parents and caregivers support their children’s literacy development in rural communities in Côte d’Ivoire. Our first study used interviews, storyboards, and prototyping methods to understand the beliefs and preferences of rural Ivorian parents for French literacy and mobile learning. Then, in the second study, we deployed an early version of a voice- and SMS-based early literacy system using low-cost mobile phones with families in one village in Côte d’Ivoire, to understand how children would use the system and how their parents would support their children without explicit scaffolds.

In my proposed work, I plan to deploy and evaluate the impact of a voice- and SMS-based literacy system that provides scaffolds for parental support for children’s early literacy, designed based on findings and implications surfaced from the first two studies. I plan to conduct a randomized controlled trial in schools in several villages in rural Côte d’Ivoire for four months, using mixed-methods approaches to understand families’ usage of the system and contextualize its impact on learning.

Through this iterative design-based research process, this thesis intends to contribute to research at the intersection of the learning sciences, human-computer interaction, and technology for development, by producing empirical, theoretical, and design contributions. I intend to provide further evidence for the important role parents and adult caregivers play in their children’s literacy development, provide initial evidence for the efficacy of scaffolding the engagement of low-literate parents in their children’s literacy - contextually grounded in rural communities in Côte d’Ivoire - and provide design guidelines for designers of technologies for early childhood literacy in developing contexts, designers of learning technologies for families, and designers of educational scaffolds for low-literate parents.
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Chapter 1

Introduction

Decades of research in early literacy learning has demonstrated the crucial role that parents and other adult caregivers play in supporting children’s literacy [54, 87]. This support may take the form of explicit instruction of letters [31] or joint reading activities [57]. In addition, parents and other adults in the home environment also model productive learning attitudes or dispositions [16], provide a supportive socio-emotional environment or "secure base" in which children may develop literacy [72], and provide a stimulating language environment for their children [34].

However, in developing contexts where overall adult literacy is low, and particularly in bilingual contexts where children are learning to read and write in a language their parents may not be literate in, parents may not be sufficiently literate to provide the most supportive home environment for their children’s literacy development [65]. The explicit instructional support described above (e.g. book reading, letter naming, and more) may be particularly difficult for low-literate parents, or for parents without sufficient self-efficacy or belief in their own literacy abilities [87, 37]. However, low-literate parents may be able to provide meaningful support in other ways, from communicating the value of literacy [16] to playing the role of a learning broker or resource provider [25, 5] by providing a productive environment for learning, to encouraging or motivating their children to persist in the face of failure [72].

Developing regions present a unique challenge and opportunity to design technologies that can support at-home family literacy practices and supplement schools’ literacy education. Côte d’Ivoire is one such developing context, where adult literacy rates lag far behind the regional and global average, (53% of adult men and 33% of adult women) [60]. 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 [39], 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 [59] suggests opportunities for technological methods to supplement in-school literacy instruction, with additional support for literacy learning in the home environment - support which may not be occurring to the extent necessary due to gaps in adult literacy in the target language.

There has been some prior work in designing mobile literacy systems for developing contexts [75, 52, 48], but with few exceptions [100, 78], 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 [100, 78]. 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 [32].
Additionally, while significant prior work has focused on how to design technologies for low-literate users in developing contexts, using interactive voice response (IVR) [63, 62, 69, 77, 76], 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 parents’ role in the social ecology of early childhood literacy acquisition, many mobile-based literacy systems are often targeted exclusively at the child, and do not account for the particular challenges of scaffolding low-literate parental support. Meanwhile, the work that has designed scaffolds for parents has been designed for literate parents in developed contexts. There is thus a need to understand how to scaffold low-literate parents and other adult supporters in providing the support for their children’s literacy in the home environment that can be most effective for their children’s literacy development.

To address this gap, we propose 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 and use of mobile devices in rural communities in Côte d’Ivoire?

**Study 2, RQ2:** How do children and their parents and other adult caregivers use a voice-based literacy system in rural communities in Côte d’Ivoire?

**Proposed Study 3, RQ3:** How do scaffolds for parental literacy support parents’ involvement in their children’s use of a literacy system, and impact their children’s literacy development in rural communities in Côte d’Ivoire?

To investigate these research questions, I am proposing a design-based research process [4, 28] to understand how to engage and scaffold low-literate parents and caregivers in supporting their children’s literacy development in rural communities in Côte d’Ivoire. I have conducted two studies to investigate the first two of these research questions, and I propose a third study to address the final question.

Our first study used interviews, storyboards, and prototyping methods to understand the ideologies and preferences of rural Ivorian parents for French literacy and learning on mobile devices in several rural communities in Côte d’Ivoire. Then, in the second study, we deployed an early version of a 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 without explicit scaffolding for their support.

Following these two studies, I thus propose a third study to deploy and study the use and impact of a voice-based literacy system that provides scaffolds for parental support for their children’s literacy, designed based on findings and implications surfaced from the first two studies. I propose to conduct a longitudinal (4-month), randomized controlled trial, with 32 schools in 8 villages in rural Côte d’Ivoire, with learning gains assessed via a pre- and post-assessment - as well as children’s performance on lessons on the system and parents’ usage of the adult supporter system, and complementing these data with home observations and interviews throughout the study.

Through this iterative design-based research process, this thesis intends to contribute by 1) having a positive local impact on children’s literacy development in several rural communities in Côte d’Ivoire, 2) providing multiple sources of evidence for potential mechanisms of that impact, and 3) contributing further evidence to developing contextually-grounded theories for family literacy learning in low-literate, rural communities in Côte d’Ivoire. This thesis is also
intended to provide further evidence for the important role parents and adult caregivers play in their children’s literacy development, provide initial evidence for the efficacy of scaffolding the engagement of low-literate parents in their children's literacy - contextually grounded in rural communities in Côte d’Ivoire - and provide design guidelines for designers of technologies for early childhood literacy in developing contexts, designers of learning technologies for families, and designers of educational scaffolds for low-literate parents.
Chapter 2

Background

In this chapter, we discuss some of the relevant background literature for this design-based research approach, including prior work on the social ecology of literacy learning in the home environment, prior work with literacy technologies on mobile devices, prior work designing technologies for low-literate users, and prior work designing systems with and for families.

2.1 The Social Ecology of the Home Literacy Environment

Many education scholars give social mediation an important or leading role in literacy acquisition [54, 33] and some have even argued that cognitive gains are socially constructed [17]. Learning scientists have long advocated for learning in the home environment as an essential complement to the literacy development that continues at school [24], arguing that designers of educational technology should design for the complex "social ecology" of children's lives [73]. Parents and other caregivers represent a crucial element in a learning ecosystem that bridges home, school, and informal out-of-school learning spaces.

Significant prior research in child development has demonstrated the crucial role that parents and the home environment play in literacy acquisition [54] - from parents’ implicit language use near their children to explicit instrumental instruction of letters, to more socio-emotional supports for literacy. In fact, a systematic meta-review found that parental involvement has a positive effect on early childhood literacy (\(d = 0.36\)) [87], but with large variance.

The classic study from Hart and Risley (1995) demonstrated the impact that parents’ vocabulary use around their children has on their children’s lexical fluency, showing that the number of words parents used around their children predicted their children’s vocabulary size [34]. Children’s exposure to language at home is not limited to such incidental exposure, but is also supported by parents’ explicit literacy-building activities such as story reading [18], letter naming [31], joint reading [57], and others (see [54] 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 [30].

In addition to the benefits of the instrumental support of book reading and letter naming [57, 31], parents provide metacognitive support for maintaining children’s attention and scaffolding self-regulation [54], as well as motivational and dispositional support by communicating to children that literacy-building behaviors have value [72, 16]. 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 [54]. 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 [24]. 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 [72]. Such socio-emotional scaffolding has been described as the "secure base" that parents and adult guardians provide for learning, wherein children feel supported in taking risks in learning [72].

However, for parents with low or nonexistent literacy, or for literate parents who are not literate in the target language their child is learning, they may be unable to provide much of the support described above. 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, or for parents without sufficient confidence in their own literacy abilities [29, 56, 96, 37]. For such parents, literacy support technologies may help supplement the literacy instruction children are receiving in school.

2.2 Mobile Literacy Technologies

There have been many literacy support technologies designed for developing contexts over the last several years, with some using tablets [94] or e-readers [79]. Given the ubiquity of low-cost mobile phones in developing contexts [59], we focus here on literacy platforms deployed on mobile phones (see [97] for a review). However, despite the extant literature on the importance of the family learning ecology in literacy development, with few exceptions [100], the majority of mobile literacy systems focus on the child as the sole agent in learning. For instance, Ojanen et al. developed a mobile app for 3G smartphones to teach children to recognize phonemes and map letters to sounds [68]. Others, such as Kumar et al., developed voice-controlled literacy apps for rural India, incorporating local cultural knowledge into games to encourage students to read words aloud [52], while another quizzed students in Zambia on the written form of various phonemes in ciNyanja [41].

Some mobile literacy systems, such as MobiLiteracy [75], Ready4K [100, 26], and Sesame Street’s literacy app [78], have incorporated approaches for parental support such as sending reminder messages for parents to teach letters, read stories, or teach literacy lessons [75]. Some of these studies did demonstrate an increase in parents’ (self-reported) frequency of joint reading [100] and letter-naming [78] 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 [75]. This suggests more work is needed to understand how to avoid replacing parents’ existing literacy activities. In addition, and more critical for the purposes of this work, these studies assumed sufficient literacy on the part of the parents to, first, read the messages, and second, to help their children learn.

2.3 Designing Scaffolds for Parental Engagement

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 [99], to Wong-Villacres et al. and Khanipour et al., who identified design guidelines for supporting parents’ engagement with schools in low socio-economic communities [98, 47]. Others, like Barron et al., have identified a set of roles that parents play as "learning partners" in the
development of their children’s digital literacy [5]. 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 [25]. 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 [5, 25]. 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 [3].

Prior research suggests that providing parents with personalized messages and reminders about their child’s performance in an educational may increase uptake of the program and may increase children’s reading ability [26]. This set of evaluations of the Ready4K! intervention [100, 26] identified that providing text messages to parents personalized by their child’s performance on standardized school assessments had a positive, statistically significant, benefit on their children’s performance, and on the parents’ uptake of the at-home instructional program. 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 [19], for a review of nudges in educational interventions). However, the parents in these prior studies were themselves already literate, and from a Western, middle-class context. It is thus not clear how effective such interventions will be with low- or non-literate parents in a rural, developing context, who may have less familiarity with the language of schooling and less self-efficacy in supporting their children’s literacy. In fact, substantial prior work suggests that parents’ engagement with their children’s education is strongly associated with the families’ socio-economic status (SES) [29] and the parents’ literacy [96]. 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 [29, 56].

Thus, it is critical to ensure that the scaffolds provided for low-literate parents’ engagement in their children’s literacy development are authentic and appropriate with how parents are already engaging with their children’s education, especially for the particular cultural-historical context of Côte d’Ivoire. To do this, we intend to draw on the lens of "guided participation", as defined by Rogoff as "the varied ways children learn as they participate in and are guided by the values and practices of their cultural communities". In this model, adults enculturate children into the behaviors, habits, and values of their community by modeling and structuring their children’s participation in actions they have reason to value [82, 81]. We will thus seek to understand the ways that parents in rural communities in Côte d’Ivoire are already communicating and enculturating their children into habits of literacy in meaningful, authentic ways for their community, to attempt to scaffold more effective, targeted support in similar ways.

2.4 Designing for Low-Literate Users

Prior research on designing mobile interactions for low-literate users suggests that voice-based interactions are the most effective for low-cost devices [63], with existing approaches typically focusing on either speech recognition-based systems, as in the SMART system [52], or interactive voice response (IVR) systems - as in the widely-used Baang and Polly systems [76, 77]. IVR systems have been widely studied in the CHI and ICTD communities [58], particularly for their effectiveness in engaging low-literate rural users, as in work on agricultural voice forums [69], grievance redressal [62], and community radio [45], among others. However, this work on IVR
systems for low-literate users has primarily targeted adults as the users of the system, and has not addressed how to design for the distributed cognitive system of parents engaging with their children's learning at home.

Another line of work from the ICTD field has explored the role of technology "intermediaries" who assist the primary user in operating technology [86, 43, 44, 67]. In their study of information-seeking in urban slums in Bangalore, Sambasivan et al. identified design considerations for low-literate users who rely on intermediaries to help them use and understand information on their devices [86]. However, in designing for low-literate parental support for literacy on mobile phones, 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 developing contexts where the official language of instruction may be a non-native language - as in French in Côte d'Ivoire - the national language policy may serve to further disenfranchise adults in rural populations who speak local languages and not the official language [1, 8, 15, 71]. 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" [9] to engage with teachers and schools [98].

2.5 Design-Based Research

In this thesis, I propose to use a design-based research approach, drawing from Barab (2014) and Easterday et al., (2014) [4, 28]. 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 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. Proponents of the DBR method argue - with others [38, 55] - that cognition is situated in particular contexts and distributed across the actors and artifacts in that context [4]. 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 [70, 84, 4]. In the DBR approach, theories are developed as theories-in-context, where the knowledge of cognition is always already intertwined with the knowledge of the socio-cultural, political, and historical context of the environment in which learning occurs.

To develop this "situated knowledge", then, researchers using a DBR method advocate for 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 [28]. 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 thesis proposal describe 3 studies, as part of a design-based research framework. The aim of this thesis is to build on a solid theoretical foundation, combined with a rich, grounded understanding of the particular context of this work, to develop a contextually appropriate design intervention, and iteratively evaluate its efficacy, aiming to ultimately contribute back to refining and developing theories of family literacy learning informed by and interwoven within the context of rural communities in Côte d'Ivoire.
Chapter 3

Study 1: Eliciting Mobile Literacy Design Guidelines from Parents

3.1 Overview

As described in Chapter 2, there remain significant open questions about how to design literacy technologies that engage low-literate adult supporters in helping foster their children’s literacy, particularly for bilingual families in developing contexts. In this study, we describe findings that emerged as part of a larger design-based research program, with a particular focus on studying the needs, goals, and beliefs of educational stakeholders (e.g., parents, children, teachers) in rural Côte d’Ivoire. In this chapter, we report on findings from nearly 60 hours of semi-structured interviews, storyboard "speed-dating" [20], and prototype testing conducted with educational stakeholders over several months, focusing in this chapter (and expanded on in Madaio et al., CHI 2019, forthcoming) on nearly 20 hours of such sessions with parents specifically, using a grounded theory method to understand the salient themes at work in our data.

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

RQ1a: What are parents’ beliefs, values, and goals for their children’s literacy in rural communities in Côte d’Ivoire?

RQ1b: What are design constraints and guidelines for a mobile-based literacy system for children in rural communities in Côte d’Ivoire?

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

3.2 Context

This study is part of a larger research program on literacy in cocoa farming communities, conducted by an interdisciplinary team of American and Ivorian psychologists, linguists, economists, sociologists, and computer scientists, which began in 2016, through a partnership with the Ivorian Ministry of Education [39, 40]. We acknowledge the cultural-historical specificity of the contexts in which we are working, and we thus 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 - the villages of Moapé and Bécoutéin in the Adzopé region, and the village of Yacolidabou (Yacoli) 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 of Yacoli had 2,822 inhabitants, Moapé 6,619 inhabitants, and the largest, Bécoutéin, had just over 24,610 inhabitants [22, 21]. 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 [89]. In our research sites, the primary ethno-linguistic units spoken by the populations is Attié, in Adzopé and Bété in Soubré.

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 Yacoli, 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 [46]. 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 [23]. In addition, despite its small size, the village of Yacoli 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. However, while 81% of children surveyed in Soubré lived in homes with running water, 36% reported toilet facilities, and 97% reported having electricity at home, none of the children surveyed in the Adzopé region lived in homes with running water, only 20% reported toilet facilities, and 83% reported having electricity at home.

3.2.3 Educational Context

In Adzopé, the village of Moapé 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 [15, 8], 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 [11]. However, that policy has not had full implementation in all schools in Côte d’Ivoire. The village of Bécoutéin (also 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 of Yacoli 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 paper, 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 [74, 2]. However, we found that across our 3 sites, children at grade 5 are reading significantly below this level, with students in Moapé reading an average of 11.7 words per minute (wpm) (SD=13.58), students in Bécouéfín reading an average of 14.7 wpm (SD=15.66), and students in Yacoli reading an average of 26.11 wpm (SD=18.88). Thus, students in the Soubré village of Yacoli are closest to reading fluency, though they still remain significantly below regional literacy levels.

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 two villages in the Adzopé region (Moapé and Bécouéfn), and one village in the Soubré region (Yacoli). 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 the 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). 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 together, which was additional evidence to us of the gender dynamics at work in the families, but was unavoidable. 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 [20] 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 [20]. All sessions were transcribed and translated prior to analysis. An example of one of the storyboard sessions can be seen in Figure 3-1.

![Figure 3-1: Storyboard "speed-dating" with Ivorian parents](image)

3.4 Data Analysis

To understand the most salient themes from our data and derive useful design guidelines for parental support for mobile literacy technologies, we adopt a grounded theory method for qualitative data analysis from Strauss and Corbin [14, 90]. Grounded theory is an abductive reasoning method that leverages the human capacities for sensemaking, curiosity, and surprise as analytic tools to make meaning and allow understanding to emerge from the data [64].

We follow an iterative approach to thematic analysis, following Strauss and Corbin (2008) by engaging 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" [90], 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, one of our 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 [90].

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, or what Brown et al. (2002) describe as "peer debriefers" [13]. 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 [14, 90].

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 support parents provide for their children's education; 4) parents' attitudes towards their family's mobile phone usage; and 5) parents' desired contexts for their children's learning. In this section, I will describe themes from our data and discuss how the local socio-economic context may influence the acceptance, adoption, and use of mobile literacy technology. I will discuss some of these themes in more depth, to exemplify our interpretive process, and the rest can be found in our CHI 2019 paper (Madaio et al., CHI 2019, forthcoming).

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.

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 to supplement the schools' education. This suggests an approach to seeking out supplemental learning resources, wherein parents play a "resource broker" role [5].

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. 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. The greater engagement parents had with schools seen in Adzopé may in fact be associated with the increased trust parents have in the teachers, as suggested by Wong-Villacres et al.’s work on parent-school engagement [98], among many others. The extent of parents’ trust and engagement with local schools thus has implications for the design of a mobile educational technology that may traverse both school and home contexts.

3.5.2 Parents’ 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 bilingual contexts, as in Côte d’Ivoire, where there are likely to be differences between the official language of instruction and families’ home language [8, 1, 36]. 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, aligned with what Bourdieu describes as cultural capital [9]. 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 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 parent’s sentiment that "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 [15, 8]. This suggests that designers of literacy technologies should understand and account for the attitudes and values that parents have towards literacy in the target language in their community.
3.5.3 Parental Support for Literacy

In addition to parents’ beliefs and attitudes about literacy, another set of themes emerged about how parents supported their children’s literacy development by communicating their beliefs and values about education to their children through advice, stories, and encouragement (similar to [72, 54], as well as more explicitly supporting their children’s literacy through instrumental support (e.g. teaching letters [87]), providing learning resources, and playing games with their children (as in [25, 5]. As one parent said:

She says that the responsibility is on both of them, that it’s her and her husband who are responsible for the child. One way or another, everyone in the house brings their grain of salt (grain de sel) in reinforcing the education of the child. [SP9]

This sense that parents marshal many people and resources in the child’s life to each bring "their grain of salt" to support their children’s education was echoed throughout all of our interviews, regardless of the level of literacy of the parents. This suggests that an educational system that intends to leverage the ecocultural support networks described by [93, 73] should account for the various ways parents in the target community are already leveraging ecologies of support for children’s learning across home and school settings.

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 [16]). 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]. This encouragement echoes other parents’ description of how French literacy will "advance the family" [SP1], and suggests that designers of literacy systems in developing contexts should consider how such systems can support parents in providing motivation and encouragement to their children, as in the "secure base" provided by parents in [54, 72].

Other parents supported their children by communicating specific dispositions for learning ([16]), 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 [42], and provides further evidence that a parent-scaffolding literacy system could, similar to [100], provide support for parents to communicate or model productive learning dispositions for their children.
Instrumental support

In addition to communicating their values about the importance of literacy and modeling effective learning dispositions, a few parents across both regions told us about how they provide what is often called "instrumental support" through explicit instructions in writing or teaching how to use the phone [54, 87]. 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 working with the teachers to help the child at home, though other parents may not trust the teachers sufficiently for this, or may not have sufficient literacy to explain what teachers meant. For parents with some literacy knowledge themselves, they described teaching their children how to read or write specific letters:

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. I do everything. [AP7]

For parents who are able to provide this instrumental support, a literacy system might scaffold their instruction with the specific letters, phonemes, or words the child is learning or struggling with. However, this level of literacy to provide explicit literacy instruction was not common among parents we met with in these communities.

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 8 families did of the 11 families we interviewed with children of eligible ages for tutoring. Paying for these tutors is one way that parents play the role of a "resource broker" for their children’s education [5, 25]. They invest in tutors - whether to fill in gaps in schools’ education or to reinforce it - as well as in physical resources, such as the slates or chalkboards described earlier, which we saw in the majority of homes we visited in both regions (see Figure 3-2 for an example), paper and writing materials for their children, or even "storm lamps" that children could use to finish their homework at night. Some parents spoke with us that, while they wanted to help their children learn, they were often too busy or tired to help their children at night. As one parent put it: "sometimes when we come back from the fields, we are tired, that’s why we hire the tutors" [AP6].

It is clear from our interviews that parents of all literacy levels support their children’s literacy development in various ways, with each "bring[ing] their grain of salt" to support their children. Some parents described communicating the value of literacy to their children, providing dispositional and motivational support. Other parents with more advanced literacy abilities describe providing instrumental support by writing letters or teaching children to use
their phones. Finally, many parents described their role as providing resources to support their children’s education - be that hiring private tutors, purchasing chalkboards to write on at home, or purchasing other school supplies. However, as described above, in spite of these efforts, children in these two regions remained well below developmental thresholds for literacy [39]. Thus, it is important to explore how learning technologies might supplement parents’ existing supports for 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 towards their family’s usage 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 (3 basic, 3 touch). 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].

Parents describe 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 sometimes 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 use the phone itself. For these parents, access to mobile devices and the Internet may provide their children access to global information resources and social networks, as in Bourdieu’s cultural
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, mostly in the Adzopé region, parents described a more permissive attitude towards their children using the phone to "play music" [AP4], "play games" [AP3], or "become familiar with what’s on the phone" [AP3].

This attitude was not present for all parents, however. Many parents described how they would allow their children to use their phone, but only after giving their permission first. This desire to give permission to the children before they could use their phone was echoed by other parents who said that without that 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.

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." [SP1]. Other 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 call the system to request a lesson, and not receive calls from the IVR system, saying "I will not let the system alone call me. I too must call the system." [SP5]. Others echoed this desire to call the system themselves, because they "would not accept" calls from the system [SP1]. This suggests that a mobile-based educational technology should account for parents’ desire to have input into their children’s mobile usage, as [35] describe in their work on balancing parental trust and control over children’s technology usage.

3.5.5 Desired Contexts for Mobile Learning

Finally, we heard themes about parents’ preferences for the contexts of their children’s learning. We presented them with storyboards showing children learning at home, at school, and in other parts of the village. Although some parents described wanting their children to use the phone during classes 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. Thus, when designing a mobile learning system that may be able to traverse home and school contexts, one must account for parents’ concerns about the safety of expensive devices across contexts.

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

In addition to wanting their children to learn together on the phones so they will all be "at the same level", 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 - she is capable and she too wants to learn." [AP3, interpreted]. 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], voicing his desire for access to the same type of "advancement" afforded by
access to French literacy described by other parents.

### 3.6 Design Implications

Given our findings, we suggest implications for design of scaffolding systems for low-literate parents in children’s literacy, particularly for developing contexts. Specifically, we suggest that designers consider how to **align parent scaffolds with families’ existing literacy activities**, at levels that are appropriate for parents’ literacy levels. For instance, as we saw in our findings, many parents are already giving advice or encouragement to their children. Thus, a mobile literacy system might call parents to provide a voice-based suggestion of specific motivational or dispositional messages (e.g. about the importance of productive failure [42] or growth mindset [27]) at specific times when the system determines that children are struggling. While this is similar to the approach taken by Ready4K [100, 78], it is important to highlight how the messages can be adapted for low-literate parents - via voice-based interactions, adaptation into parents’ local language, or adoption of parent-generated messages through a co-design process with parents, as in [99].

Further, we suggest designers of mobile literacy systems **design for the multiple actors in the family’s learning ecology**, including parents, but also siblings, older relatives, neighbors, or even home tutors, if present in the community. We believe (following many others [54, 87, 65] that early literacy interventions that only target the child (e.g. [97]) are missing opportunities for additional socio-emotional as well as instrumental support for literacy development. Many parents described to us their compensation strategies for supplementing their own low literacy - some giving their phone to "intermediaries" such as their siblings or even children to help them read and compose text messages [86], or enlisting their numerically literate children to write phone numbers on the walls in chalk. It is clear in our data that literacy is supported through multiple means and by multiple actors in the larger social ecology of the family (as in [93, 73]).

To leverage this support, designers might 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 (as in [92, 61, 94]). Additionally, 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 as in the "collaborator" or even "co-learner" roles of Barron et al. [5], where they are learning the concepts, but in such a way to spare them the potential embarrassment or "face-threat" of learning the same lessons as their children [25]. This might also take the form of designing for parents or other adults to be what Sambasivan et al. refer to as technology "intermediaries" [86], who may be able to support children’s digital literacy skills, even if they aren’t able to support their French literacy development (as in [94]).

Finally, we suggest that designers of mobile literacy systems **consider the tradeoffs of children’s autonomy of learning on the mobile device**. Given what we heard from parents about their concerns for children’s respect for the phone and parents’ airtime credits, designers of mobile educational systems may consider designing methods for parents’ to influence the contexts and limits of their children’s usage of the phone, as many others have discussed [35]. This may involve having the system engage with the parents as intermediary first, to allow them to have input into the context of learning by calling in to the system. Indeed, while some prior mobile literacy systems involving parents (e.g. [100, 78, 75] sent parents a scheduled text or call, parents in our data described wanting to determine when they or their child accesses the system.
3.7 Discussion and Conclusion

Parents and the home environment are crucial elements of children’s social ecology for learning early literacy [54, 87, 73]. Yet for families in low-resource contexts, children may lack a home environment without reading materials or sufficiently literate adults to effectively provide stimulating literacy experiences, a situation that may be exacerbated in bilingual contexts where the language of instruction may be different from families’ home language [66, 65]. Mobile devices, ubiquitous even in developing contexts [59], may offer one way of supplementing children’s family literacy environments [97, 75], but they must account for parents’ beliefs, attitudes, and desires for children’s literacy and use of mobile devices in order to be effectively adopted and used. Even if designers of family literacy technologies intend for them to be deployed exclusively in out-of-school contexts, given our findings, it is critical that designers understand the complex socio-political ecologies of families’ language learning in their community context. Particularly for low-resource contexts, or those where families’ language and culture may not be aligned with that of the teachers and schools, or where parents may feel alienated from engaging with teachers and schools [98, 36, 12], it is increasingly critical to consider that larger social ecology when designing the system’s curriculum as well as the deployment and usage methods.

Educational technologies, particularly literacy technologies, are always situated in the local socio-political landscape of the languages (and by extension, cultures), which are valued by society and welcomed at school [36, 12, 88]. In bilingual contexts, particularly in former colonial contexts where the official national language - and the language of instruction in schools - is the language of the colonizers, it is thus critical to understand and attend to the ways in which literacy is politically charged, and the values and goals that stakeholders (here, parents) have for their children’s literacy [71]. Technologies that teach literacy thus have the potential to either further reify the majority linguistic group’s dominance over literacy education [36, 71], or they could demonstrate to minority language speakers that their language has value and importance in the development of multiple literacies in a bilingual context.

In this study, we identified some beliefs, goals, and desires of rural Ivorian parents for their children’s literacy, in order to elicit design guidelines for a parent-child literacy technology, situated within the Ivorian socio-cultural context.

We find that parents in rural Côte d’Ivoire view French literacy as providing access to what Bourdieu describes as cultural capital [9] - that French can be a means for their children to access jobs and opportunities throughout Côte d’Ivoire, jobs which may not be present in their village, given current economic conditions. Given these desires, and the prevalence of families speaking the local language at home, we intend to address these concerns by first bootstrapping children’s literacy by using shared phonemes between the local language and the target language [39], and then by providing some instructional support messages to parents recorded by local speakers in the local language.

Additionally, designers of family literacy technologies should consider the role that various family members play as intermediaries in their children’s learning, as [86] describe [86]. Parents may be the intermediaries in helping their children navigate the use of various functions of the mobile phone, as seen in Uchidiuno et al.’s work on adult support of digital literacy in Tanzania [94]. Or, as in one family we spoke with, the children may teach their parents functions of the phones as they become more comfortable with them through using the phone to read. However, designers should be aware of the tradeoffs associated with solely relying on parents as intermediaries. As many others have described [44, 67, 85, 91], women and girls in many rural contexts may find their access to mobile devices limited by the men in the family. This is corroborated by GSMA’s recent study on the global gender gap in access and usage of mobile
technologies, where they highlighted Côte d’Ivoire as having a particularly high gender gap (22%) in women’s access to mobile devices relative to the region [83].

This study provides further evidence for the importance of considering ideologies about literacy in bilingual contexts, the relationship between parents and schools, and parents’ attitudes towards children’s use of technology, and we highlight design guidelines for mobile literacy systems to scaffold parental support for their children’s literacy. In the next chapter, we describe Study 2, in which we developed and deployed a mobile-based literacy system using interactive voice response (IVR) and SMS to provide lessons in phonological awareness and print-sound mapping to children in one village in Côte d’Ivoire.
Chapter 4

Study 2: Deploying a Mobile-Based Literacy System with Families

4.1 Overview

In Study 1, in spring 2018, we identified parents’ beliefs, goals, and preferences for their children’s literacy using interviews and storyboard speed-dating to elicit design guidelines for a parent-child literacy system. We then used those design guidelines to inform the design of a mobile-based early literacy instructional system. In Study 2, in fall 2018, we deployed a functioning version of our early literacy instructional system with 38 families in one village in rural Côte d’Ivoire. This system provided 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. Because of the critical role played by parents and other family members in providing a supportive environment for developing literacy (see Chapter 2 for more detail), we conducted a set of 24 home observations to investigate whether and how parents and other adults in the family were already providing such support to their children using the system - despite the version of the system deployed in Study 2 not having any explicit scaffolds for parental support.

As the second phase of a design-based research approach, we thus investigate the following research questions in Study 2:

**RQ2a:** What are children’s patterns of usage and learning performance when using a mobile-based literacy instructional system in rural Côte d’Ivoire?

**RQ2b:** How do parents and other adults support their children’s use of a mobile-based literacy instructional system in rural Côte d’Ivoire?

4.2 System Design

To investigate these research questions, we designed a functioning version of a voice-based literacy system for phonological awareness and print-orthography mapping, to help us understand how parents and adults are already supporting their children’s usage of the system and helping with the literacy content. In this section, we describe the phonology curriculum, the system architecture for the interactive voice response system, and discuss 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 [53, 10], we target this set of fundamental skills as the intervention in this study. This curriculum was developed by a team of linguists from the University of Delaware with whom we are collaborating [39], and who have conducted substantial prior research into extant literacy rates in Côte d’Ivoire [39, 40]. 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 the full curriculum, with example questions provided for each unit.

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

Figure 4-1: Phonological Awareness Curriculum

4.2.2 Interactive Voice Response System Architecture

Because our population of learners and their parents is likely to be low- or non-literate [60, 39], we implemented the curriculum on an interactive voice response (IVR) system, to provide instructions, lessons, questions, and feedback via pre-recorded voice messages, and allowing for the selection of responses with numeric touchtones. This follows many others in the ICTD community [63, 69, 62, 77, 76] in using IVR for designing for low-literate users. To implement the IVR on the local Ivorian telecom networks, we have partnered with a local education technology company, Eneza Education, based in Kenya, with an office in Abidjan, Côte d’Ivoire. 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 4-2 for a visualization of the system architecture.

At the start of each call, the system plays a welcome message for the users, updates them on their progress in the curriculum, and begins the lesson. Based on the user’s previous per-
formance, they are provided with questions from the unit they are currently working on. Each unit has a set of unique questions designed to teach the overarching concept from that unit in a slightly different way. See Figure 4-3 for examples of questions from the first 4 units. Because for this study we did not yet have data on the respective difficulty of each of those question types, they were chosen randomly. During Study 2, we collected performance data on each question type, and we will thus determine the appropriate question-level mastery thresholds for selecting each question type in the proposed Study 3.

Each lesson begins with an explanation of the type of question presented in that lesson, an explanation of how students are expected 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, lists the 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. See Figure 4-4 for an example call flow demonstrating the delivery of instructions and questions. Based on the response to the question, the students receive feedback that the response is not correct, or feedback that the response is correct. If it is incorrect, the question is presented again, with a hint message provided, explaining the concept or prompting the student to focus their attention on a particular part of the word or syllable. After two wrong attempts, the answer is provided, with a brief explanation, and the system provides the next question.

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
feet 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...
the 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 Ananguié and which 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" screen, and 8mb internal memory for storing SMS messages, 2G network accessibility, which is available in most parts of Ananguié [59], 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.

Figure 4-5: Itel IT5231 Mobile Phones

4.3 Context

In this study, we were working in the rural village of Ananguié, in the Adzopé Department, in south-east Côte d’Ivoire. Ananguié is primarily a cocoa-producing region, with a population of 13,786 at the last census in 2014 [22, 21]. The primary language groups are Attié, Kulango, and Dioula, and the primary source of income is growing and selling cocoa. Located along the same highway from the regional center of Adzopé as is Moapé and Bécouéfin, there is regular foot traffic and private buses and vans that provide the main source of transportation between Ananguié and the surrounding villages, while within the village, the main source of transportation are motorcycles, or motos. There are four schools in Ananguié, with one of
those being the bilingual PEI school. We were working in one school (EPP-1) for this study, though we met with the heads of the other schools and the head of the local COGES (Comité de Gestion d’Écoles, or school organization committee) to obtain approval for the study. See a map of Ananguié in Figure 4-6.

![Map of Ananguié](image)

**Figure 4-6: Map of Ananguié**

### 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 Pre-assessment and Phone Training

This study lasted for seven weeks, from October 24th, 2018, to December 12th, 2018. Participants were all 38 students in the CM1 class (equivalent to 5th grade in the US) in one school (EPP-1). At the beginning of the study, we gave a pre-test to the 38 children in the study, on the types of skills they were learning during the lessons. These include items on phonological awareness, 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. This also includes items on phonology-orthography mapping, such as grapheme identification (e.g. "what is the name of this letter or group of letters? "ch"), reading common words (e.g. "mal") and invented words (e.g. "tipa"), sentence reading, and comprehension of simple stories.

Prior to deploying the system, we gave a two-hour training session to at least one adult in each family in the study, explaining the purpose of the study, distributing the Itel phones, teaching them how to use the phone and how to call in to receive lessons and answer questions, and asking them to have their child call in every day for the next seven weeks.
4.4.2 Home Observations

Then, during the next several weeks, I visited 24 families at their homes, along with an Ivorian member of our research team, to observe how the children participated in the lessons and how the parents supported their children during the lessons. We called each family to schedule a time to visit, and only these 24 (of the 38 families in the study) had either working phone numbers or answered our calls. For each of these 24 families, we scheduled a time to visit when they would normally be calling in for a lesson. See Figure 4-7 for a list of the children’s gender, the parent who was present during the lesson, and the parents’ primary source of income. The primary income source of most families in the study was cocoa farming, though there were two tailors, a teacher, and a cocoa distributor. In these families, half were boys and half girls, and we met with 7 mothers, 6 fathers, 4 brothers, 4 sisters, and 2 aunts who accompanied the child during their lesson. These families were geographically quite distributed across the village, with some located quite near the school, and others several kilometers away, living in predominantly Muslim communities near the local mosque, or in minority language groups, such as Kulango and Dioula.

In each visit, we explained that we wanted to observe the normal scenario of calling and completing the lessons, to the extent possible. While there was likely some effect of the two of us in the room observing, we tried to be as unobtrusive as possible. After we observed a call for roughly 20 minutes (or until the user hung up), and took careful notes (as well as audio and video recordings) of how the adult present provided support, we asked the adults a set of interview questions. These questions centered around how the adults help their child learn - in ordinary circumstances as well as with the mobile device - as well as questions about their beliefs and goals about education and French literacy, similar to Study 1.

![Figure 4-7: Description of participants in Study 2](image-url)
4.5 Findings

4.5.1 Key Findings from Home Observations

After conducting these observations and interviews with families at their homes while the child used the system, we identified some key insights about the nature of children’s usage of the system, the ways in which their parents or guardians are already supporting them, and some preferences the parents expressed for how they could get involved in other ways.

Adult supporters accompanying children during the session

First, one major insight was that almost every family we visited did have a parent or other adult who helped them use the phone to call in for the lessons, though the nature of that support varied widely. While we had hypothesized that we would see this, based on our previous findings in Study 1, we were encouraged to see 21 of 24 of the participants who we visited at home have an adult who was present and helping during the session. The other 3 participants had adults present in the home environment when we went to observe, but they sat on the other side of the room, or were engaged in other activities (e.g. washing laundry, cleaning fish, making a cassava dish called fofou, etc), and were not paying attention to the child’s call. When we asked them afterwards why they didn’t get involved, each of those 3 parents told us they didn’t speak French, and no one else in their immediate family spoke enough French to help.

Adult supporters providing different types of help

For many of the adult supporters we observed, the support they provided was in demonstrating or directing the child how to use the mobile device itself. Adults often helped the child call the number for the IVR system, turn the phone on hands-free, and offered suggestions and feedback for pressing the touchtone numbers to respond to the questions and navigate the menu. For some adults, their support took the form of listening to the instructional messages and question prompts and repeating the answer options or emphasizing the specific sound prompts the child was asked to listen to. For instance, for the question: "Which word ends in ‘am’? Nom, Femme, Bonne", several adults would repeat the sound /am/ louder so their child could hear and attend to it, while others would repeat "Nom, Femme, Bonne". Other adults interrupted the lesson on the call to demonstrate how certain words rhymed. They would either repeat these verbally, or write them in chalk on a nearby chalkboard (as we saw in many homes in Study 1 as well as again here in Study 2), or, in some cases, would write the letters with a stick in the dirt or with a pencil on paper. However, these examples were not always the questions the child had had the most trouble with on the call, but may have been the most recent ones they heard, or were question types (e.g. choosing the rhyming pair) that the adult felt more comfortable giving support on.

Other children present during the lessons

In all but one of the families we visited, the child participating in the study was surrounded by many more children who lived with them, from 1 (two families) to up to 10 (three families). Some of these children were their siblings, while others were cousins or relatives of other family members who lived in the same housing group. In many of the families, these children gathered around the primary participant and observed them calling in, watching and listening as they completed questions and lessons. In some families, these children were mimicking and mirroring
what they saw from their older sibling using the phone - with one child repeating the question prompts in a sing-song voice, and another child drawing letters with a stick in the dirt while listening to the lesson. As we described in the Background section, there are motivational, cognitive, and socio-emotional benefits for learning with peers or sibling near-peers [61, 94, 82, 80]. This suggests design opportunities for leveraging the other children in the household to help motivate and reinforce what the children are learning through the system.

Figure 4-8: Older sister helping her sister and a cousin

Multiple children learning together

In some families, the other children nearby were of the same age (10-11, in grade CM1) as the participants, and for some families, they were also participating in the study as well. We visited three such family groups, where multiple children, often not siblings, but cousins or neighbors with a shared caregiver, would gather together to learn with their phones, under the supervision, and sometimes with the help of, a single adult. However, while these adults appeared to have sufficient literacy to teach the concepts from the lessons, they did not always know which types of questions, concept, or phonemes the children needed the most help with, and did not appear to tailor their instruction to the content the children needed the most help with.

In one of these families (Figure 4-8), we observed two cousins learning with the older sister of one of them, who was helping them both. The sister set up a large chalkboard and asked the two participants to both call in with their respective phones at the same time. Unfortunately, because the phones were both on hands-free, it was difficult for either child to clearly hear the instructions and questions they were given. In addition, the specific questions and phonemes given to each child were different, and so the sister had difficulty choosing a single lesson to instruct them on to help both of them. Nevertheless, she wrote out an example question on the board that she heard from the call (e.g. "Which does not belong with the others? 1) salle, 2) car, 3) mal"), and asked the two girls to write down the number of the answer on two smaller chalkboards she gave to each of them. However, it was not clear why this question type was
chosen, of all the possible questions these children were receiving, nor why this set of answer choices (which may have fewer distractor items, and therefore be an easier question). Thus, it was not clear that this support was that which was most needed by these two children, nor that it would be most beneficial for their learning.

In another example, a group of four children - all cousins - met regularly with the older brother of one of them, who was a cocoa farmer and regularly traveled to the nearby town of Adzopé, but who made time to help his younger sibling and cousins when he was in Ananguié. When we observed this group, the brother explained to the children what they would learn and how they could call, then directed each one to call in individually, while the other 3 sat and listened to the call (Figure 4-9). After one of the children answered several questions incorrectly, the brother intervened and explained the concept (identifying similar phonemes at the end of words), using a piece of chalk to write words and letters on the table. However, in this group, one of the children was already in Unit 2 of the curriculum, while all of the other children were in Unit 1. It did not appear that the support the older brother gave this girl was targeted at different skills or concepts appropriate for her unit, thus suggesting that a scaffolding technology might be better able to help adults personalize the instrumental support they provide their children - or younger siblings.

![Figure 4-9: Adult observing and giving advice on a lesson](image)

**Issues identified**

Finally, through the home observations and interviews with family members, we surfaced a set of concerns and issues that parents raised. First, and most urgently, several parents told us that they were never informed about the purpose of the study or why their child was given a phone. Although we held a training and information session for families at the outset of the study, not all caregivers attended this session, and in two cases from the families we visited, the family member who attended the training and returned home with a cell phone did not communicate the purpose of the study or the phone to the primary caregiver responsible for the child. As
such, when we met with those parents at their home to observe the lesson, they informed us that their child hadn’t yet used it because they didn’t know the purpose of why we gave their child a phone, reinforcing findings in Study 1 about the importance of trust and communication between various educational stakeholders at the school and at home.

For other families, the issues faced were more about not fully understanding how the system worked or how their child was supposed to use the IVR system to respond. For instance, in one family - the older sister who was helping the two girls at the same time - the adult didn’t understand that the children needed to press the numeric buttons on the phone in order for the system to track their progress and have the children advance in the curriculum. Those two participants had been answering their sister verbally and on the chalkboard, but not responding to the question prompts on the phone. Other children had issues with waiting to hear all of the answer options presented before pressing the button, and occasionally pressed a button that was not one of the answer options or pressing multiple buttons in response.

4.5.2 Key Findings from Call Log Data

In addition to the qualitative data collected in the home observations and interviews, we also obtained quantitative data logged through all of the interactions of our 38 users for the seven weeks of the study, logged each time they call in. This has allowed us to investigate patterns in usage across the seven weeks, such as the number of days each users calls, how long they spend on the calls, and other information about the calls. We also have performance data on which questions each user was provided on a given call, their performance on those questions, including the number of attempts per question, and their progression through the units of the curriculum.

We found that while many students called in regularly for the duration of the study, others had many days where they did not call in at all. By the second week of the study, daily calls had dropped to half of the participants in the study, in the third week, daily calls had dropped to a third of the participants, and by the fourth week, average daily callers were a quarter of the total number of participants. Most users tended to call in after dinner, with the most common time being 7:00pm, likely after dinner. There was a small spike in users calling in between 12:00pm and 2:00pm, as the children return home from school for lunch. The average length of call was substantially shorter than the estimated time we anticipated for the calls.

As in many similar learning systems, some students were able to progress through the curriculum, while others remained in the first unit, repeatedly being given the same types of questions. We also saw differences in children’s performance across the question types within each unit. For this study, we used a mastery threshold to govern the unit-level progression, but this suggested that we should be adapting the curriculum at the question-level in addition to the coarser-grained unit level.

4.6 Design Implications

As a result of these findings, we identified a set of design implications to improve the design of the literacy system used by the children and to design an IVR system to provide scaffolds for adult caregivers to more effectively support the children in their care. First, the gaps in the daily calls into the system, and the overall decline in children calling in suggests the need for ways to motivate students to continue calling in to the system for lessons. Drawing on prior literature on motivation, as well as findings from our observations and interviews with families,
We identified a set of design opportunities for motivating students to continue to call into the system more frequently.

These include providing motivational content like stories or word games or drawing games taught via voice instructions, which children could play offline, but which would be "unlocked" at intervals throughout the curriculum. Additionally, this might include scaffolding the parents in motivating their children by telling them about the value of regular practice for literacy development, the importance of these types of lessons (e.g. phonology) for literacy, and giving them personalized information about their children's call frequency and recent performance, to suggest that parents encourage or motivate their children following gaps in calling, or recent dips in performance.

Further, the number of students who had difficulty progressing through the curriculum (even after consistently calling in to complete lessons) suggests opportunities to better support students who are "wheel-spinning" [6]. Some possible ways we might do this are: using an adaptive method of item selection, providing more remedial support in the form of examples or hints to better support students on the specific questions they had difficulty with, and involving the parents or other adult supporters by telling the adults the specific types of questions and content their child had difficulty with, and providing them some suggestions for other ways to explain that concept to their child or practice it in new ways after the IVR call.

Finally, for the parents who were not aware of the purpose of the study, and as a result prohibited their child from calling in for lessons, we intend to provide information about the purpose of the study and the intended use of IVR system for their child (e.g. answering the questions to advance to the next levels), as well as information about the importance of phonology for developing literacy. Because several of the families in our study had no adults who spoke sufficient French to understand the calls, we intend to provide some of these informational messages in some common local languages for this region (e.g. Attié, Kulango, Dioula), which a message suggesting they find a French speaking adult who could provide support or help to the child in the study.

### 4.7 Discussion and Conclusion

Given the recent conclusion of Study 2, we are still in the process of analyzing the qualitative data (e.g. using a grounded theory method) and the quantitative data (e.g. for statistical analyses of the relationship between system usage and learning gains). However, we were able to identify some key findings from preliminary data analysis which have proved useful in informing the re-design of the voice-based literacy system for children, and informing the design of the adult literacy supporter system.

The design-based research method is an iterative process [28], with each phase of the process, from understanding to problem definition to conception, design, development, to evaluation providing opportunities to reflect and return to the other phases with a more informed understanding of the context and the phenomena. Thus, from Study 2, we have elucidated initial findings about how families in rural communities in Côte d’Ivoire are already using and engaging with a voice-based literacy system accessible via low-cost mobile devices. For Study 3, we can then design a system informed by these findings that can be appropriate for the needs, desires, and goals of members of these communities, may have a positive impact on the children who use it, and which may contribute to theories-in-context of family-based literacy learning in low-literacy contexts, situated within rural communities of Côte d’Ivoire.
Chapter 5

Proposed Study 3: Scaffolding Low-Literate Adult Support for Children’s Literacy

5.1 Overview

The preliminary work we did in Study 1 helped us to understand design considerations in designing technology for scaffolding low-literate parental engagement in children’s literacy in rural communities in Côte d’Ivoire (Study 1: Madaio et al., CHI 2019 [forthcoming]). Then, the work we did in Study 2 allowed us to understand the usage and impact of a voice-based literacy technology in rural communities in Côte d’Ivoire (Study 2). In Study 2, we identified ways that low-literate parents and other caregivers were already providing support for their children’s literacy when the children were using an educational literacy technology. As others have suggested, providing brief nudges and personalized messages to parents to suggest specific ways to support for their children’s literacy may be successful in prompting more parental participation in early literacy interactions [100, 78]. However, such interventions have typically taken place in Western, middle-class families in urban contexts, with literate parents. Thus, for low- or non-literate caregivers in rural families in developing contexts such as Côte d’Ivoire, it is not immediately clear that such approaches will be successful. As Barab and Squire, among many others, have argued, the nature of learning in complex, authentic learning environments is that the process for learning and the context itself are intertwined, with cognition distributed across the multiple actors in the learning ecology [4, 28, 55].

Thus, as the final phase for a design-based research methodology, we propose a study to evaluate the usage and efficacy of a mobile voice-based literacy system which provides adaptive instruction to children, while also providing messages for adult supporters suggesting supporting their children’s burgeoning literacy. We thus propose a study to investigate the following research questions:

**RQ3a:** How do voice-based scaffolds for parental support impact how parents engage with their children’s use of an early literacy system in rural communities in Côte d’Ivoire?

**RQ3b:** How does parents’ usage of an adult literacy supporter system impact their children’s usage of a literacy technology in rural communities in Côte d’Ivoire?

**RQ3c:** How does parents’ usage of an adult literacy supporter system impact their children’s literacy development in rural communities in Côte d’Ivoire?
5.2 Proposed Study Design

To investigate my primary research questions - (RQ3a) how voice-based scaffolds for parental support may impact parents’ involvement in their children’s literacy, and how parents’ usage of such a system may impact (RQ3b) their children’s usage of a literacy system and (RQ3c) their subsequent literacy development - I propose to conduct a longitudinal randomized experimental study of children and their parents’ use of a mobile voice-based literacy system that provides direct instruction to children and provides personalized scaffolds for support from parents.

The design-based research methodology entails an iterative process of understanding, designing, building, and testing an educational intervention situated in the rich, complex, learning environments in which authentic learning occurs in context [28, 4]. Thus, the proposed Study 3 follows from the work done in Study 1 and Study 2 by iterating and expanding on the design of the system used in Study 2, informed by findings from both Study 1 and 2, and evaluated in an ecologically valid experimental study triangulated with observations and interviews with participants. This study, as the final phase of a design-based research methodology [4], is intended to contribute by 1) having a positive impact on participants’ literacy development, 2) providing evidence for potential mechanisms of that impact, and 3) contributing evidence to developing contextually-grounded theories for family literacy learning in low-literate, rural communities.

5.2.1 Experimental Study Design

First, at a high level, based on prior literature suggesting that providing instruction on phonological awareness and letter-sound mapping will be beneficial to children’s literacy [10, 53], particularly when such instruction is adaptively targeted to the appropriate difficulty level for each child [49, 95], I hypothesize (RQ3.H1) that there will be a positive relationship between families’ usage of our literacy system and children’s literacy learning gains between a pre-test and post-test, when compared to a control group of children whose families are not provided with such a system.

Then, based on prior literature on providing nudges to parents to help their children with literacy activities, I hypothesize (RQ3a.H2) that there will be a positive relationship between parents’ usage of the scaffolding provided on the adult system and their explicit motivational, dispositional, and instrumental support for their children’s learning (observed at multiple points throughout the study). Finally, I hypothesize that there will be a positive relationship between parents’ usage of the adult supporter system and (RQ3b.H3) children’s frequency of use of the literacy system and (RQ3c.H4) children’s learning gains. To adduce evidence for these hypotheses, I propose a longitudinal randomized controlled trial (RCT), supplemented with qualitative home observations and interviews with families throughout the study.

Based on power calculations based on prior data on literacy assessments in rural communities in Côte d’Ivoire [39, 40], our team determined an appropriate sample size to detect an effect, given the intra-class correlation of literacy within the various hierarchical levels (e.g. students, in schools, in villages). We calculated that we would need 16 schools in the control condition and 16 in the treatment condition, across 8 total villages, with one class (CM1) in each school, assuming an average of 40 students per class (based on data collected during Study 1 and 2), to detect an effect size of at least $d = 0.4$, with a power of 0.80, at an alpha value of $p = 0.05$. Schools will be randomly assigned to each condition, and a randomization check will be done to ensure that the average class size in the control condition is not significantly different than that of the treatment condition. In the next section, I describe the system design, and then discuss the data that will be collected, and potential analyses.
5.3 System Design

5.3.1 Voice-Based Early Literacy system

To address the above research questions, we have designed a mobile voice-based literacy system, as described in Study 2. Following the design-based research methodology, we have iterated on the design of this system - from prototypes tested with children in Study 1, to a 6-week deployment of this system in Study 2. Because we propose to work in similar contexts in Study 3 as in Study 1 and Study 2, we anticipate families’ existing access to and experience with low-cost, "feature-phone" mobile devices will be equivalent, thus motivating the use of low-cost mobile devices here in Study 3 as well. Similarly, given the low levels of children’s literacy in rural communities in Côte d’Ivoire identified in Jasinska et al. [39], we anticipate that literacy levels in our target grade level (CM1) will be similar in the villages we are proposing to work within in Study 3. We are thus proposing to use the same early literacy curriculum as in Study 2 - targeting phonemic awareness first, and then progressing to simple and complex letter-sound mappings. See Figure 4-1 and 4-3 for more detail on the proposed curriculum. However, given the findings from Study 2 about children’s usage of the system, we have iterated on the design of the literacy system to incorporate elements suggested by our findings and design implications from Study 1 and 2.

Adaptivity

Although Study 2 did use adaptive progression at the Unit level of the curriculum - progressing students to the next unit only after they had sufficiently mastered the previous unit - it did not provide such adaptivity at the lower-level of the questions provided to students. In part, this was because we did not yet have evidence for whether the "knowledge components" (or, "an acquired unit of cognitive function or structure that can be inferred from performance on a set of related tasks" [50]) should be represented at the question-level or the phoneme/syllable-level.

In Study 2, we found evidence for differences in children’s performance based on the type of question they were answering, but we did not see similar differences in their performance on questions with different types of syllable structures (e.g. simple syllables, complex syllables, etc). Thus, for Study 3, we propose to incorporate adaptive item-selection - adapted at the level of the type of question [95]. That is, when selecting the individual type of question within each unit (e.g. rhyming questions, onset-sound questions, sound-belonging questions, etc), the system will initially choose these randomly, as in Study 2, but when students complete more questions, it will then select questions based on children’s mastery of individual question types (as in [95]).

Further, because we observed many children remaining in the same unit after many (e.g. several hundred) question attempts, despite calling in consistently for many days, we propose to incorporate explicit support built into the system for what others have referred to as "wheel-spinning" [6]. In part, we propose to provide additional instructional examples or hints to children for the specific types of questions they are wheel-spinning on. We also propose to incorporate suggestions for parents or other adult supporters to provide help on these specific question types, as part of the adult supporter system, described in more detail in Section 5.3.2.

Motivational elements

In Study 2, 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. To address this,
we propose two modifications to the child’s literacy system that may help motivate children to continue participating (in addition to designing an element of the system targeted at adult supporters to address this). Based on prior work that suggests that including games into an educational curriculum that are progressively "unlocked" as children advance may be motivational [68, 41], we propose incorporating literacy games that children can play with each other and with their adult caregivers.

In Study 1 and 2, we prototyped several literacy game options with children that they could play with each other "offline" without needing to be on 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, to having the IVR system provide these instructions to children (Study 1), to 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 to play after the researchers ended the session.

5.3.2 Adult Literacy Supporter System

Substantial evidence from prior literature suggests that parents play a crucial role in the development of children’s literacy [87, 57, 54]. Further, evidence from prior work and our own prior studies (Study 1 and 2) suggests that parents, particularly low-literate parents, may need additional scaffolding for the support they provide for their children’s literacy. We have thus designed a portion of the literacy system which provides such scaffolds to parents via interactive voice response (IVR) and SMS-based system, accessible via the low-cost mobile devices ubiquitous in developing contexts [60, 59]. To do this, we have identified a set of high-level design goals, informed by prior literature and evidence from our previous research with families in rural communities in Côte d’Ivoire, and developed a set of features of an IVR system to instantiate those design goals. These design goals are to 1) provide information about the value of phonology for literacy, information about how to use the system and the purpose of the study, and the importance of regular practice for literacy; 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 parents about the types of questions their children are most struggling with and providing suggestions for help, to providing more generic suggestions for involvement in their children’s literacy development.

First, we (1) intend for this system to provide parents and other adult supporters with sufficient 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 seems crucial to the successful uptake of an early literacy system. This is particularly important given the significant role parents play in modeling and communicating values for the role and importance of literacy to their children [16, 54]. In Study 1, we saw parents telling us of the importance of literacy
to advance their families, but without the connection made between the distal goal of literacy and the immediate gains that children are making on phonemic awareness, parents may not communicate these values to their children.

Secondly, we (2) have designed scaffolds for parents to provide motivational and socio-emotional support to their children at an appropriate time. While parents in Study 1 told us that they often provided encouragement to their children in their education, and we observed some parents in Study 2 giving such encouragement during the lessons we observed, it is not clear that this encouragement is 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 the child is feeling most frustrated with). More generally, [54, 72] 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 not all parents may have the self-efficacy for literacy themselves to feel comfortable playing the role of what Barron [5] calls the "learning broker", in arranging the conditions for their children’s learning, and providing such socio-emotional supports [37, 29]. Further, even parents with such self-efficacy may not know when or how to effectively motivate their children. Therefore, we have designed messages to inform parents about, first, the patterns of system usage by their children - either consistent streaks of calls or gaps in children calling in, and reminding them to encourage their child to continue calling in if they have lapsed. This follows from prior work [100, 51], 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 in supporting parents’ instrumental help with the system and content itself. As we observed in Study 2, many parents are already spontaneously providing assistance and advice to their children during the lesson, without prompting or scaffolding from us. However, such parents may be those who are already literate, thus leading to a potential "rich get richer" effect. Further, as we observed in Study 2, even parents with sufficient literacy to write out letters and words on their chalkboards may not know enough about the specific questions their children are struggling with to offer help that will be targeted where it is most needed. Parents in Study 2 told us repeatedly that they wanted to know more about what types of lessons their children were receiving, since they often couldn’t hear the questions on the call, or weren’t present during the lesson. Given that the parents in Study 2 who were helping their children with the content didn’t know which types of questions their children were struggling with, we will provide parents with summaries of the concepts children are currently learning, as well as providing parents with personalized information about the specific types of questions their child is currently struggling with (based on their performance data on that question type), with hints and examples for the parents to help them help their children. These design goals were then instantiated into an IVR call flow (as in the example shown in Study 2) and written into messages recorded by an Ivorian speaker working with the Eneza Education company we are partnering with for the system implementation.

5.4 Proposed Data Collection

5.4.1 Learning Assessments

Students in both conditions will be given a pre-assessment of phonological awareness and print-rhyme mapping at the outset of the study and an isomorphic post-assessment at the completion of the four months of the study (as in Study 2), as well as given a survey at the beginning of the study to identify potential covariates such as socio-economic status (i.e. number of resources
in the home), absences from school, parental source of income, and other items. Students in
the treatment condition only will be given a low-cost feature mobile phone for the duration of
the study, loaded with sufficient credits to make calls to the IVR system. We will also provide
a brief training session for each child and an adult in their family on the purpose of the study
and how to use the device (as done in Study 2 as well), given in groups at the school, with our
Ivorian research collaborators providing the training in small groups.

5.4.2 Call Log Data

In addition to these pre- and post-assessments, we will obtain log data from the participants’
usage of the system, for both the children as well as the parents. As in Study 2, we will obtain
data on the number of calls, length of calls, performance on the lessons on each call (for each
specific question type), and other data such as number of attempts on each question type,
the number of lessons each child needed to complete each unit, whether adaptive support for
"wheel-spinning" was needed, and more. In addition, we will also obtain data on the parents’ or
caregivers’ use of the adult supporter system, including the frequency and timing of their calls,
as well as the options that parents are selecting (e.g. performance updates, lesson support,
learning games, etc), to understand the relationship between their usage of these items and
subsequent performance data from their children.

5.4.3 Home Observations and Interviews

In addition, because the log data of parents’ usage of the adult supporter system will only allow
us to know what they are choosing to listen to on the call, but, crucially, not how they use that
information, we will conduct home observations and interviews, as in Study 2, to observe how
parents are supporting their children during the lessons. This use of qualitative and quantiative
data is suggested by Barab and Squire [4] as one method for obtaining ecologically valid evidence
to contribute to theories-in-context in design-based research methodologies [4]. Much like in
Study 2, the observation protocol will consist of both unstructured observations of the lessons,
as well as some prompted activities and a semi-structured interview protocol thematically similar
to the interview protocol for Study 1 and Study 2.

This will allow us to adduce further evidence for our hypotheses about the relationship
between the scaffolds our system provides for parental support, the observable aspects of the
support parents and caregivers provide for their children’s literacy during the lessons we observe,
and their children’s system usage and learning gains. We propose to conduct these observations
of parents across the villages in the study, at intervals throughout the study, including, but not
limited to, the first and last month of the study.

5.5 Proposed Analyses and Evaluation

Finally, to investigate our hypotheses for our research questions, I propose several analyses of our
data. First, for our overarching hypothesis in this study (RQ3.H1), I will conduct a mixed-effect
hierarchical linear regression model to understand the relationship between condition (control
and treatment) and learning gains from pre- to post-assessment, while controlling for other
factors from our survey and call log data (e.g. family socio-economic level, system usage, etc).
The hierarchical levels in this data will be families, within schools, within villages. For two
other hypotheses for this study (H3, H4), I propose to use similar hierarchical linear models to
understand the relationship between parents’ usage of the various support elements of the adult
supporter system and their children’s system usage (H3) and learning performance (H4). The hierarchies here (families, within schools, within villages) will allow us to tease apart the effects of parents’ usage of the adult supporter system from any random effects of the school or village. We will attempt to conduct omnibus tests whenever possible, rather than multiple individual tests, and will conduct appropriate post-hoc corrections for multiple hypothesis testing (e.g., Bonferroni or Benjamini-Hochberg [7]).

Finally, as in Study 1 and Study 2, I will conduct a grounded theory analysis of the home observation and interview data, using transcriptions of the interviews and observations as well as the video data itself to inform the development of the codes, in collaboration with other members of our research team, both here at CMU as well as our Ivorian collaborators. These data will help us adduce evidence for RQ3b and H2 (how parents’ use of the adult supporter system impacts the nature of the support they provide their children during lessons), as well as helping us to triangulate, contextualize, and better understand the mechanisms underlying our findings from the other research questions.

5.6 Conclusion and Anticipated Contributions

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 in low-resource communities may lack the literacy to effectively support their children at home. As mobile devices become increasingly ubiquitous across developing regions, they have the potential to provide scaffolds for family support for children’s literacy development in low-resource areas where local schools struggle to reach every child.

In the first stages of this thesis, I have conducted two studies as part of a design-based research process to understand and scaffold low-literate parents and caregivers in supporting their children’s literacy development in rural communities in Côte d’Ivoire. Our first study used interviews, storyboards, and prototyping methods to understand the ideologies and preferences of rural Ivorian parents for French literacy and learning on mobile devices in several rural communities in Côte d’Ivoire. Then, in the second study, we deployed an early version of a 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 without explicit scaffolding for their support.

Following these two studies, I thus propose a third study to deploy and study the use and impact of a voice-based literacy system that provides scaffolds for parental support for their children’s literacy, designed based on findings and implications surfaced from the first two studies. I propose to conduct a longitudinal (4-month), randomized controlled trial, with 32 schools in 8 villages in rural Côte d’Ivoire, with learning gains assessed via a pre- and post-assessment - as well as children’s performance on lessons on the system and parents’ usage of the adult supporter system, and complementing these data with home observations and interviews throughout the study.

Through this iterative design-based research process, this thesis intends to contribute by 1) having a positive local impact on children’s literacy development in several rural communities in Côte d’Ivoire, 2) providing multiple sources of evidence for potential mechanisms of that impact, and 3) contributing further evidence to developing contextually-grounded theories for family literacy learning in low-literate, rural communities in Côte d’Ivoire. This thesis is also
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intended to provide further evidence for the important role parents and adult caregivers play in their children’s literacy development, provide initial evidence for the efficacy of scaffolding the engagement of low-literate parents in their children’s literacy - contextually grounded in rural communities in Côte d’Ivoire - and provide design guidelines for designers of technologies for early childhood literacy in developing contexts, designers of learning technologies for families, and designers of educational scaffolds for low-literate parents.

Given the crucial role that parents and adult caregivers play in providing a supportive, stimulating home environment, to complement the learning environment children experience at school, it is critical to understand how we may support parents in low-resource, low-literacy communities in providing a stimulating home literacy environment for their children.

### 5.7 Timeline

My goal is to complete the thesis by spring 2020. The table above presents a timeline for the next year and a half.
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