DIA: Supporting Teacher Professional Development in Low Infrastructure Settings

CMU-HCII-23-106
August 2023

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This dissertation is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Keywords: HCI; ICTD; HCI4D; Communities of Practice; Teachers; Teacher Professional Development; Teacher Training; Conversational Agent; Chatbots; Aspirations;

Abstract

Governments in developing countries aim to improve education through novel teaching approaches as taught in pedagogical programs. These pedagogical programs rely on government teacher training infrastructure and face challenges in rural parts of Africa where there is a lack of experts and teachers are isolated. Thus, pedagogical programs consider using technology to overcome some of these challenges.

Prior work has used a conversational agent to address the challenges of limited expert knowledge and providing personalized interactions. Recent work used virtual communities on social media for teachers to support each other through online interactions. Still, it is unclear how these two promising research areas can translate to rural African contexts with low technology infrastructure. Additionally, teachers in these contexts are newly adopting technology and thus require additional support to accommodate technology adoption. Therefore, there is a need to discover appropriate conversational agent designs that support teacher communities in low-infrastructure settings.

This design process must overcome several practical, technological, and theoretical challenges to find appropriate designs in this context. Beyond being usable, the design has to support an intervention aligned with the pedagogical program. Lastly, theoretical grounding for designing technology in low-resource contexts is still emerging.

Therefore, I use an iterative design-based research (DBR) approach by working closely with teachers in rural Côte d'Ivoire to develop a technology that helps them to implement a pedagogical program. My work iteratively identifies design directions and validates these directions through prototypes shared among the teacher community. Through a progression of three studies (Study 1, Study 2 and Study 3), I studied the impact of these design directions at scale.

My work led to a conversational agent called "DIA." that I designed by working with Ivorian teachers. Key findings in these studies were that teachers supported each other in the community and valued community-based features in a conversational agent. Therefore, this led to my thesis question: ***How does a conversational agent that supports a virtual community of practice (vCOP) impact teachers in low***

infrastructure settings?. To answer this question, I conducted a large-scale, year-long study to understand the impact of community-based features at scale (Study 4).

Study 4 involved a longitudinal quasi-experiment with 400 teachers in two different regions of rural Côte d'Ivoire to investigate the impact of two variations of a conversational agent. In one region, a conversational agent with individual support was deployed, and in another region, a conversational agent with community support was deployed. The objective was to assess motivation, knowledge, and technology adoption changes over the school year. The findings indicated that community support positively affected motivation, enhancing agency within the community. Teacher knowledge showed some improvement, with a slight but statistically significant overall increase. Although the community condition increased technology usage, the results did not reach statistical significance. The results favor utilizing community support in conversational agents for teachers in low-infrastructure settings.

This dissertation extends the literature on Human-Centered AI in low-infrastructure settings through iterative design-based research. On the theoretical front, my work expands literature on virtual communities of practice to an Ivorian context. My work has created opportunities to design for teachers "aspirations" or long-term desires. My work has also provided design recommendations for governments to utilize a conversational agent to support teachers implementing pedagogical programs.

Dedication

> *Happiness can be found, even in the darkest of times, if one only remembers to turn on the light.*
>
> **— Albus Dumbledore**
> (Headmaster of Hogwarts)

I dedicate this dissertation to my first teacher –my grandmother, the late Mahamayi (1932-2023, known as Amuma to me). Amuma, you taught me to read my first alphabet. You also shaped my worldview by teaching me the importance of compassion during my early childhood. You lit up my world in many ways. I hope I've shared some of your light (DIA) with the world through my Ph.D. work.

Acknowledgement

I'm thankful to my fantastic advisors and committee, the real stars of my PhD journey. My advisors were my strongest allies and amazing colleagues throughout these challenging years. I hope we continue collaborating in the future. I am very grateful to Prof. Tim Brown for believing in me long before any Ph.D. program accepted me. I am incredibly thankful to the universe (and Prof. Jen Mankoff) for letting us work together for the past six years. Even after all these years, I still look forward to every interaction with you as they are fun and intellectual. I am very grateful to Prof. Amy Ogan for taking me on as her student and letting me work on this fantastic project. I admire her intellectual prowess as a researcher and her kindness as a human being. She always inspires me to improve daily. I also want to thank my committee members (Prof. Chinmay Kulkarni, Prof. Mayank Goel, and Prof. Kentaro Toyama), who channeled my research into the excellent work it is today. I am lucky to have a compassionate and supportive committee who have helped me grow as a researcher through their thoughtful suggestions and ideas.

I thank the PIs of the SEME project (Dr. Kaja Jasinska, Dr. Sharon Wolf, and Dr. Samuel Kembou) who supported my research and provided me with ample resources to succeed. I am grateful to Kaja Jasinska for allowing me to borrow her Ivorian research team multiple times on short notice. I am also thankful to TaRL Africa for supporting me during my research. Thank you: Marion Paravicini, Carla Campos, Ndoye Awa and Amos Dembele. Thanks to their support, understanding, and patience, this project was successful. I am also grateful to the outstanding students (or my team, DIA) who helped the project evolve into this impactful intervention. I'm blessed that you chose to work with me: Huhgette Sandrine, Marie Claudine, Justin Souvenir Niweteto, Eloisa Avila Uribe, Maya Greenholt, Baptiste Moreau-Pernet, Adela Kapuscinska, Egide Nizerimana, Lena Armstrong, Tricia Ngoon, Neil Thawani, Ren Butler, Lesley Yan, Aastha Patel, Prithika Acharya, Safiyyah Scott and Christine Niyizamwiyitira. I'd also like to thank Michael Madaio and Evelyn Yarzebinski, who helped me kick-start my research in the Côte d'Ivoire by welcoming me into Allo Alphabet and the OH lab. I'm grateful for our research team in the Côte d'Ivoire who patiently helped me with my work and struggles as a vegetarian: Adji Yves, Hermann Apke, Fabrice Tanoh, Salem Konan, Roger Apahou, and team Proterrain, who made this project possible during the pandemic. I am grateful to the IPA team, particularly Armand Degla and Romuald Anago, for collecting the data.

Even today, I feel blessed that I got accepted into and got to work as a Ph.D. student at the Human-Computer Interaction Institute. My journey at HCII has allowed me to work with kind and supportive people who have allowed me to grow as a researcher and a person. I am thankful to our academic advisor, Queenie Kravitz, who motivated me over the years; you are a gift to the HCII community. I am grateful to a few community members: Tomohiro Nagashima (and family), Lynn Kirabo, Nur Yildirim, Sai Swaminathan, Prerna Chikersal, Stephanie Valencia Valencia, Samantha Reig, Julia Cambre, Franceska Xhakaj, Nesra Yannier, Judith Uchidiuno and Sujeath Pareddy and among many others who've played a unique role in my PhD journey. I want to thank my former mentors: Rita Singh, Bhiksha Raj, Aaditeshwar Seth, Neha Kumar, Ken Koedinger, Michael Bett, Michael Best, Mamello Thinyane, Scott Hudson, Jen Mankoff, and Geoff Gordon - I am fortunate to have learned from you all, and you've played an integral part of my research saga. I am grateful to my HCIxB family: Rama Adithya Varanasi, Camellia Zakaria, Aakash Gautam, and Karthik Bhat, among many others - who constantly encouraged me and lent a helping hand over the years. I'm lucky to have friends like you; thanks for your kindness and feedback over the years.

I am grateful to my Pittsburgh family, who have given me a life outside of my Ph.D., especially to Viji Sooriamurthi and Raja Sooriamurthi, who came into my life as fairy godparents and accepted me into their wonderful family. I am blessed to have taught my Kannada students, Vipanchi, Swati, Abhinav, Sanvi, Adrith, and Monishka, who taught me more than I can ever teach them. You are a wonderful gift! I am lucky to have you in my life. I am particularly grateful to my colleagues (and the parents) at the SV Temple classes: Premalatha Mylarappa, Prashant Krishnamurthy, Deepika Devarajan, and Gayatri Hebbar, among many others. Thank you for including me in your beautiful circles.

I am blessed to have friends from NITK, Kenmawr, TeliportMe, CMU Africa, Ivuka Arts Kigali, and CMU who've supported me in numerous ways. I want to thank my kind friends Shwetha Macheri, Siddharth Sivaraman, and Ravikumar Krishnamurthy for helping me get through my struggles by patiently listening to my rants. I am very grateful to Dr. Lynn Harper for helping me improve my mental health during a few difficult years during the pandemic. I also want to thank Dr. Mengchun Chiang from CMU CAPS, who helped me overcome a difficult semester.

I'm grateful to my fantastic relatives and family, who supported me remotely through regular phone calls. A special thanks to my cousin Vikas Argod, whose encouragement was crucial to my Ph.D. and USA journey. My loving family: Annu, Amma, Akka, and Vigi, whose love and kindness helped me persevere through this challenging journey. Thank you, EVERYONE!, for being my light. I am blessed to have you all in my life.

Contents

Declaration

We thank Jacobs Foundation and a fellowship from Carnegie Mellon University's Center for Machine Learning and Health for funding this work.

Parts of this document were used from prior publications by the author:

[Study 1] Vikram Kamath Cannanure, Justin Souvenir Niweteto, Yves Thierry Adji, Kaja Jasinska, Timothy X Brown, and Amy Ogan. Im Fine Where I Am, but I Want to Do More: Exploring Teacher Aspirations in rural Côte d'Ivoire . *In: Proceedings of the 3rd ACM SIGCAS Conference on Computing and Sustainable Societies. COMPASS 20*. Ecuador: Association for Computing Machinery, 2020

[Study 2A] Vikram Kamath Cannanure, Timothy X Brown, and Amy Ogan. DIA: A Human AI Hybrid Conversational Assistant for Developing Contexts. *In: Proceedings of the 2020 International Conference on Information and Communication Technologies and Development. ICTD2020. Guayaquil, Ecuador: Association for Computing Machinery, 2020*.

[Study 2B] Vikram Kamath Cannanure, Eloísa Ávila-Uribe, Tricia Ngoon, Yves Thierry Adji, Sharon Wolf, Kaja Jasinska, Timothy X Brown, and Amy Ogan. 2022. We dream of climbing the ladder, for getting there, we have to do our job better: Designing for Teacher Aspirations in rural Côte d'Ivoire. *In ACM SIGCAS/SIGCHI Conference on Computing and Sustainable Societies (COMPASS) (COMPASS 22)*, June 29-July 1, 2022, Seattle, WA, USA. ACM, New York, NY, USA, 26 pages. https://-doi.org/10.1145/3530190.3534794

Vikram Kamath Cannanure

1 Introduction

Today, school enrollments in low and middle-income countries are growing exponentially, but basic primary school educational outcomes still lag international standards [139, 158], thus impeding economic growth and equity [12]. Early simulations show that COVID-19 has aggravated this situation, and up to 91% of students will fall farther behind in Sub-Saharan Africa [13]. Governments are addressing this crisis by investing heavily in new pedagogical programs that deliver targeted instruction to align with student learning levels [89]. Successfully implementing these pedagogical programs requires well-trained teachers, but programs for training teachers in low-income countries are challenging to deploy. As pedagogical programs scale, they rely on governments' teacher training [89][1] infrastructure to teach new approaches and provide support to teachers. However, implementing teacher training interventions in rural and isolated areas is challenging due to infrastructural [24, 90] and socio-cultural complexities [185, 123]. This gap is prominent in sub-Saharan Africa, especially in rural areas with less economic infrastructure, such as roads and energy supply [4]. Therefore, pedagogical programs consider technology to scale and increase their impact [89].

Technology has shown promise in teacher training interventions in some contexts, but how this body of work can support designing technology for rural African contexts is unclear. Prior projects have supported teacher training by providing resources digitally through tablets [124], videos [168], and audio contexts [116]. These interventions are often new to the context, leading to overhead investments in setup, training, and monitoring costs [124]. Recent work has reduced the overhead of introducing new technology by capitalizing on teachers' own devices and using applications, such as WhatsApp, that are already familiar to users [87, 128, 155]. Literature has also shown the benefits of creating virtual communities(VCOPs) for teachers to support each other using technology [176, 200]. Teacher support groups on WhatsApp have allowed fostering of virtual teacher communities in Indian [203] and African contexts [132], but connectivity issues prevent streamlined access and participation of rural teachers [132]. Additionally, there tend to be fewer administrators in rural Africa [24, 90], who are critical to facilitating and moderating these groups digitally [132].

[1] Also referred to as teacher professional development or professional learning.

Conversational agents, also known as chatbots, are one way to support scaling expert knowledge and have seen initial success on social media in rural African contexts [31]. Some conversational agent research has scaled expert knowledge using innovative AI techniques in Western settings [86, 171]. An exploratory deployment of a conversational agent on WhatsApp in rural Côte d'Ivoire by the authors [31] found initial evidence that such technology can provide personalized and context-specific support to teachers. However, AI research is often disconnected from low infrastructure contexts due to socio-cultural nuances [169]. Prior work has attempted to bridge this disconnect [220, 127, 93, 31] through qualitative design studies with stakeholders. Therefore, there is a need for design-based work to understand the potential for conversational agents to support teachers in low-infrastructure settings.

To design impactful systems, Toyama [198] urges researchers to extend traditional HCI approaches that understand user needs [136] and follow an *aspiration-based approach*, i.e., to channel user aspirations while designing technology. The objective is to shift researcher thinking from problem-solving for user needs to support users to achieve their aspirations with technology [198]. Toyama describes an aspiration as an individual's *long-term desire that is persistent and aiming for something higher than one's current situation* [198]. Understanding aspirations has shown to have practical benefits for developmental projects [162, 71] as well as theoretical benefits [10], which improve research transferability for the HCI4D space [44]. Although research on aspirations has emerged in education [142], student's career [165], and healthcare [148], research on teacher aspirations is still developing. Therefore, I use a theoretical lens of aspirations to uncover conversational agent design directions to support teachers in implementing pedagogical programs in low-infrastructure settings.

However, finding appropriate designs for this problem faces practical, contextual, and theoretical challenges. On a practical level, the context of the teachers' and the pedagogical program along multiple dimensions was unknown to the researchers. Additionally, beyond being usable to users who are new to technology use [48], the design had to conceive an intervention aligned with the goals of both the teachers and the professional development program. Lastly, on a theoretical dimension, aspirations are relatively emerging in low infrastructure contexts for technology, thus increasing the complexity of designing for new populations, such as teachers implementing pedagogical programs in rural Côte d'Ivoire.

To overcome these challenges, I used a *design-based research*(DBR) approach [18, 52] by working closely with teachers implementing a pedagogical program in rural Côte d'Ivoire. DBR work helps researchers work in a new context and understand contextual knowledge using mixed methods, i.e., qualitative and quantitative data

collection methods. Throughout my work, I followed a DBR approach with teachers and ministry officials in rural Côte d'Ivoire to uncover conversational agent designs. My work involved sharing prototypes among community members, through which I iteratively identified and validated the design directions. In my final study, I use this knowledge to understand the impact of the resulting designs and generate theories in context.

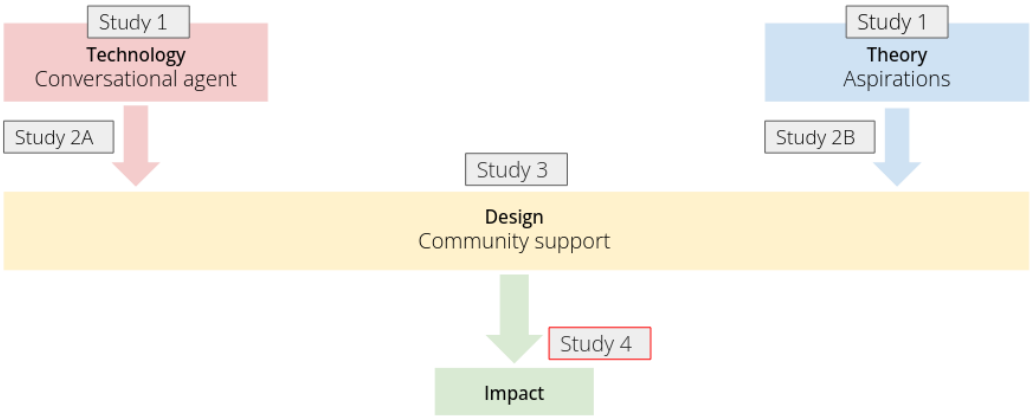

Fig. 1.1.: The iterative design-based research to bridge the gap between theory, technology, and design through my former studies (Study 1-4). My final study (Study 4) is to answer: ***How does a conversational agent that supports a virtual community of practice (vCOP) impact teachers in low infrastructure settings?***

Therefore, I conducted three studies (refer Fig 1.1) as part of a design-based research process to support teachers implementing a pedagogical program in rural Côte d'Ivoire. My first study used a qualitative approach to explore technology's role in teacher professional development. Then, in the second study, (a) I deployed and evaluated an early version of a conversational agent (DIA) (b) my interview data revealed the positive role of community support in teachers' engagement in a pedagogical program. Finally, in the third study, I updated my conversational agent designs with features for community support through participatory content. My preliminary analysis revealed that teachers valued community-based features.

Therefore, this led me to my thesis's question: ***How does a conversational agent that supports a virtual community of practice (vCOP) impact teachers in low infrastructure settings?***. To answer this question, I evaluated the impact of community support designs in a conversational agent through a longitudinal, large-scale deployment. I have categorized impact as teacher motivation, training knowledge, and technology adoption. I hypothesized that community support features would have a better impact than individual support due to early adopters, who will support their fellow teachers through the intervention. Therefore, I ran a longitudinal study in two regions receiving community or individual support.

Study 4 involved a longitudinal quasi-experiment with 400 (313 verified) teachers in rural Ivory Coast to investigate the impact of two variations of a chatbot. One version with individual support and the other with community support(vCOP) within a teacher training program. The objective was to assess motivation, knowledge, and technology adoption changes. The findings indicated that community support positively affected motivation, enhancing teachers' professional agency within the community and reducing emotional exhaustion. Teacher pedagogical knowledge increased over time only for the ASER category for active users. Although the community condition improved technology usage, the results did not reach statistical significance.

My work makes a case for virtual Communities of Practice(vCOP) and chatbots in low-infrastructure settings. My dissertation adds to the gaps in literature by providing insights for:

- *Design*: I conducted a series of iterative studies using Design-Based Research [18, 52] to create features for the chatbot to facilitate a virtual community of practice for rural teachers.
- *Participation*: My findings revealed new ways rural Ivorian teachers engage offline and use technology intermittently.
- *Content Moderation*: My designs have offered initial evidence of chatbots to support content moderation for virtual communities of rural teachers.
- *Evaluating impact*: I ran an experiment to assess the impact of the virtual community of practice by conducting a longitudinal study involving over 400 (313 identified) teachers.

Outside academic impact, this thesis supports practitioners and policymakers through:

- *Designing for teacher aspirations theory*: As aspirations are relatively emerging in low-infrastructure contexts for technology, my work extends the theory to aspirations-based designs. I expect my approach will help ICTD practitioners convert theory-based work on aspirations to practical design-based interventions.
- *Initial evidence of social impact*: My work will also provide initial design recommendations for governments to utilize conversational agents to support teachers in implementing pedagogical programs in rural African contexts.

2 Related Work

In this section we summarize the related work spanning teacher professional development, technology to support teachers in developing contexts, designing for aspirations, and lastly, intelligent messaging in low-resource contexts.

2.1 Pedagogical Programs and Teacher Training

In recent years, developing countries have invested in novel pedagogical programs to address the learning needs of primary school students [89]. These programs teach students foundational skills tailored to their learning levels [195]. The level-appropriate teaching for students and tailored guidance from facilitators help the students improve at their pace [210]. Prior work has used community volunteers, learning camps, and teachers as facilitators to guide students to enhance their foundational skills [16, 17]. Teachers have shown to be ideal for sustaining these programs in sub-Saharan Africa [56, 64, 191]. African governments have operationalized these programs using their teacher professional development infrastructures [56, 64]. Pedagogical program deployment differs from typical teacher training programs because they have more resources (financial, operational) and rigorous evaluations to understand their impact [89]. However, they also receive many of the same benefits and challenges as teacher training programs.

Significant research on teacher training tells us that ongoing and lifelong professional learning is integral to supporting teachers [65, 186, 98, 92]. Research has found that giving teachers *expert feedback* in person for their teaching sessions [22] through thoughtful reflection is an effective approach. Prior work on modeling teacher growth informs that teacher growth is non-linear; therefore, teacher training programs should consider building individual teacher capacity with *personalized* support [39]. Teacher training literature in the Global North has developed material to foster self-efficacy [15], self-reflection [173], and collaboration [40], some via interactive tools [68, 84]. However, how this work transfers to developing contexts where experts are less readily available [24] is unclear.

Although teacher training programs have been shown to improve children's education in developing countries [125, 157, 50, 17] it is challenging to implement

them in rural contexts [133, 50, 90]. Teacher training interventions often require a cultural shift [185, 123] in which teachers are asked to change some of their long-held teaching beliefs and practices, making it difficult for teachers to implement the pedagogical approaches of a new program without frequent mentoring [4]. In developing contexts, teachers are mentored through regular visits by ministry officials [90]. Still, infrastructural challenges (i.e., poor roads, travel costs, etc.) and lack of mentors reduce the frequency of mentoring visits [133, 24], leading to challenges in teacher training implementation. Hence, it is helpful to support teachers in rural contexts who might need more mentoring and support in implementing these pedagogical programs.

2.2 Teacher Training and Communities of Practice

An alternative perspective is that PD is informal, and teachers learn through interactions between themselves [55]. Prior work has explored creating formal learning communities but creating traditional structures is not sustainable as it takes more resources [79]. Additionally, learning occurs in a context, i.e., informal discussions among teachers during school hours [126]. Therefore research has advocated for promoting informal teacher communities that allow unstructured social learning [11, 137].

Prior work has used a theoretical framework called communities of practice (COP) to understand informal teacher communities [213]. The defining traits of a community of practice are a domain, a community, and practice. The *domain* includes a shared field of interest, such as teaching. The *community* consists of a group of people, i.e., teachers, who meet formally/informally regularly. Lastly, the *practice* includes a shared repository of knowledge about the domain, i.e., experiences, stories, and material distributed among the community members. Wenger [213] postulates that repeated interactions between new and active members allow new members to learn and become active eventually. Wenger [213] also suggests that the initial participation of new members is "peripheral," i.e., they participate passively to learn for a period before they start gradually contributing (as active members) and eventually become core members who contribute at a high frequency.

COPs have been shown to benefit teacher communities when they have collaborative activities and dialogue between members [112]. Lesser & Prusak [114] argue that collaboration in COPs helps build relationships with other community members, which helps them learn and shapes the future direction of their work. Additionally, creating unique channels that allow for meaningful conversations

between active and novice teachers also leads to novice teachers learning and integration into the community [53]. Lastly, these conversations have to be sustained over time to create a meaningful impact on teachers' learning [146]. Although COPs have shown promise for educators, a bottleneck for sustaining COPs is their need for in-person interactions, which is challenging in developing countries due to geographical limitations [90]. Therefore literature suggests augmenting existing COPs with technology [89, 176].

2.3 Virtual Teachers Communities of Practice

Virtual communities of practice(VCOPs) use online technology to allow communities to interact beyond geographical limitations [149]. VCOPs use technology to allow for virtual participation among members to share stories and have discussions to solve problems related to their domain [97]. Participation in online communities can be active and peripheral. Active participants regularly add content, i.e., ask questions, share stories, or perform tasks. Peripheral members consume content but do not regularly contribute [149]. Prior research has shown that it is normal for a large section of users in online communities to participate peripherally [159]. Still, peripheral participation is essential as members learn from reading information that may not be available elsewhere [73].

Significant research on virtual communities suggests that technology needs to be designed to augment an existing community, and a VCOP is independent of any technology([177]). To design virtual communities, prior work [83] suggests focusing on (1) connections: linking people in the same practice, (2) content: providing a shared repository of information resources, (3) conversation: support communication by providing discussion tools, and (4) information context: providing users context about the shared content. Outside technology design, Wenger et al. [214] suggest that technology shepherds are an integral component of an online community. Technology shepherds are early adopters who train and encourage usage among novice users leading to greater technology adoption. Lastly, even after careful designs, members will ultimately use technology as they see fit and how it was designed to be used [149].

VCOPs for teachers found that teachers use online tools when they see a perceived benefit, i.e., teachers are motivated to access pedagogical resources and improve social connections [176, 200]. To support teachers' access to resources, prior work recommends personalized interactions that cater to each teacher's needs [176]. On the social side, experienced teachers (or teachers with higher self-efficacy) are likelier to share content [200]. Sharing on online media is motivated by offline

interactions, and technical systems would benefit from increased social interaction between novices and experienced teachers [200].

Although VCOPs have supported teachers in Western contexts, it is unclear how technology can support teacher communities in low infrastructure context [75, 81] where internet access may influence technology adoption.

2.4 Designing Technology for Teachers in Low-Infrastructure Contexts

Although technology has shown promise in education in developing contexts, a large portion of the research is focused on giving resources to children [144, 105, 202] or supporting school administration [164, 66, 41]. Prior projects that focus on teachers have helped them with *teaching resources* through video content [7, 168, 124], audio content [116], and text messaging [99]. Still, it is not clear that simply providing teaching resources is sufficient to support teachers in implementing novel pedagogical programs [89]. Additionally, introducing new technology requires extra digital training and monitoring to promote engagement [124].

Prior work has mitigated training and monitoring costs using popular social media applications, such as WhatsApp, which is a familiar tool for teachers [87, 128, 155]. In Indian contexts, NGOs have extended technology support beyond teaching resources by creating groups [216] to foster peer support and remote administrative help for a VCOP of teachers [203, 204, 205, 135]. In particular; these initiatives showed success in decreasing teacher absenteeism.

However, internet technology [128, 31, 33] in rural Africa is still lagging behind its Global South counterparts like India [75, 81]. In rural Côte d'Ivoire, a related project by Motteram et al. [132] found initial evidence that Whatsapp groups could support the VCOP of language teachers. Still, rural teachers lagged on usage due to connectivity issues. [132]. In rural contexts, teachers use the internet infrequently or in specific locations due to low cell tower infrastructure [31, 132]. Therefore, to understand this design space, we extend the literature on WhatsApp-based support for teachers, specifically for pedagogical programs in a rural context like Côte d'Ivoire where infrastructure is emerging [75, 81].

2.5 Designing for Aspirations

To build sustainable systems [147] for Information and Communication Technology and Development (ICTD) some researchers have shifted focus from user needs [136] to designing for users' aspirations [198]. Toyama describes aspiration as an individual's *long-term desire that is persistent and aiming for something higher than one's current situation* [198]. Learning user aspirations has shown to have practical benefits [162, 71] as well as theoretical roots [10] which improve research generalizability for the ICTD research [44]. Therefore, prior work in ICTD has explored aspirations in mental health [148], healthcare [101, 91], community networks [51], agriculture [77] and accessibility [103]. In education, prior work used aspirations to understand career paths for high school students [110], undergraduate students [100, 165] and vocational workers [194].

For African teachers, aspirations have been explored for pre-service undergraduate teachers' aspirations (i.e., teachers in training) in South Africa [26]. In prior work by the authors [33] on primary school teacher aspirations in Côte d'Ivoire, we discovered teacher aspirations for (1) *Students' success*: teachers expressed that they wanted to see their students improve on the curriculum over the short term and improve professionally in the long term; (2) *Improving teaching skills*: Teachers expressed aspirations to improve their teaching skills to support their class better; (3) *Career progression*: Teachers aspired to progress in their career to become advisors and inspectors to have a broader impact on the community. However, we discovered aspirations for career progression conflict with their current teaching role, complicating the design space. Therefore, this paper explores how these aspirations intersect with the pedagogical program to design relevant technology for low infrastructure settings.

To design for aspirations, Kumar et al. [110] showed that aspirations are deeply intertwined with the community (*embedded*), aspirations are achieved after a time frame (i.e., have *temporal* boundaries) and can adapt with time (*mutable*). Additionally, Kano al. al [100] found the importance of role models in influencing the future aspirations of undergraduates in Bangladesh. In Côte d'Ivoire, we [33] found that teachers' professional aspirations conflict with their teaching responsibility. However, teachers' role models help them navigate this conflict between current aspirations (to support students) and future aspirations (to advance their careers). These insights, like Kumar et al. [110] and Kano et al. [100] have implications for designing systems that not only support interface design but also lead to developmental outcomes or better lives for marginalized users.

2.6 Intelligent Messaging in low resource settings

Early work in text messaging focused on sending one-way messaging [47, 161] to provide information to the user but users found it challenging to interact without feedback. Therefore, projects have moved towards providing two-way feedback for health [152], education [218], and agriculture [209] with expert support. Researchers have extended expert support to create human-machine hybrids in finance [46] and healthcare [151] by automating a part of the interaction. However, text messaging-based applications are limited by the cost of messaging, reducing sustainability and lack of availability of experts reducing scalability [152, 151, 218]. To improve sustainability, research has shifted to use text messaging on social media in education [203], healthcare [63], activism [172], and election monitoring [131]. However, this work on text messaging through social media platforms depends on experts' availability, which is a scarce resource in developing contexts.

Chatbots or conversational agents have the power to scale up expert knowledge through artificial intelligence [74]. The first chatbot Eliza was developed in 1966 to emulate a therapist using simple rules of language understanding [212]. Today chatbots are being used by 1.4 billion users on various platforms on home assistants and social media platforms like Skype, Whatsapp, and Facebook [182, 62]. On Facebook Messenger alone, it is estimated that there are 300,000 chatbots [182]. Chatbots have been classified based on usage [62], customer support agents for product search (Alibaba), personal assistant chatbots (Amazon Alexa, Google Home) for content curation (CNN News) and coaching (WoeBot [141]). Prior work has tried to scale chatbot capabilities by using human-machine hybrids [74] or humbots that combine expert knowledge with innovative AI techniques [86]. Additional research has expanded chatbots through Crowd-AI hybrid architecture to automate conversations over time [86] by utilizing crowd workers to support AI when it fails to retrieve an appropriate response. Additionally, prior work has used chatbots to mediate experts critique learners in short intervals of time on social media [197]. A chatbot has also been used to foster a community of practice for teaching staff in in the US [167]. However, a majority of this work is focused on western settings in the English language [182] which may not transfer to developing contexts due to lack of language datasets or translation support leading to a further need to rely on experts. In developing contexts, prior work has focused on a voice-based chatbot for low literate users [94] and explores design opportunities for novice urban users interacting with Facebook Messenger chatbots [95]. However, more research is needed to explore opportunities to design chatbot-based systems to support local language interaction using text messaging in low resource settings.

2.7 Conclusion

In sum, some pedagogical programs have successfully improved teaching practices, but they must be adapted to support rural teachers in low-infrastructure settings. Teacher communities can help each other professionally through organic informal expert-novice interactions. Recent work has been shown to support such interactions for teacher communities virtually on social media such as WhatsApp. However, it is unclear if chat applications like WhatsApp–which many teachers worldwide use–can help teachers sustainably in rural Sub-Saharan Africa with low internet infrastructure. Prior work in ICTD has proposed an aspirations lens to design sustainable interventions, but it is unclear how teacher aspirations intersect with new implementations of pedagogical programs. Lastly, conversational agents have shown promise to support scalable interventions, but it is unclear how to translate such interventions for teachers in places like Côte d'Ivoire. Therefore, we explore this design space for pedagogical programs in developing rural contexts.

Study 1: Exploration

3

> *I'm fine where I am, but I want to do more*
>
> **— P14**
> Exploring Teacher Aspirations

3.1 Overview

Fig. 3.1.: The goal for study 1 was to explore the (a) technological design space in Côte d'Ivoire and (b) discover opportunities to design for teachers' aspirations.

In this chapter (refer Fig 3.1), I explore the design space for teacher professional development in developing contexts with technology. Prior work in ICTD has proposed an aspirations theory to design sustainable interventions, but it is unclear how teacher aspirations intersect with their professional development or technology. Therefore, we interviewed 22 teachers across two regions of rural Côte d'Ivoire over two years to understand their aspirations and how it influences their professional development and technology use.

3.2 Research Questions

To address this, we use the *aspirations-avenues-agency* framework [107, 110] to analyze our qualitative study. *Aspirations* translate to longer-term desires [198], *Avenues* are pathways both traditional and non-traditional that users take towards fulfilling their aspirations and *Agency* is the capacity that people build to create these avenues [107] (e.g. *Aspiration: Teachers want their students to excel in class*, *Avenue: They use technology to captivate children's attention*, *Agency: They download technology-based classroom examples*). This framework lead to the following research questions:

RQ1: What are the aspirations of teachers in low-resource contexts in rural Côte d'Ivoire?

As professional development is a key to teacher growth we ask:

RQ2: Through what avenues do teachers currently access and implement professional development?

To see whether technology can have a role in this growth we ask:

RQ3: What agency do teachers currently have to support their professional development with technology?

3.3 Methodology

This study is part of an ongoing research program on supporting literacy in cocoa farming communities, conducted by an interdisciplinary team of American and Ivorian researchers. The project aims to improve children's education in rural Côte d'Ivoire through poverty reduction and improved educational quality. For this study, we interviewed 22 teachers from 2 regions of Côte d'Ivoire (Adzopé and Soubré), the interviews were conducted in 3 sessions from April 2018-May 2019. We transcribed, and translated the interview data into English and formed the low-level themes using grounded theory [36, 188, 134] and used affinity diagramming [25] to synthesize the themes for our research questions.

3.3.1 Participants and Data Collection

With approval from the Ivorian government and our university IRBs, participants were introduced to us by the school director who was first briefed about the study. The interviews were conducted with voluntary verbal approval from the participants who were offered no compensation. The data collection was conducted in French by an Ivorian researcher with help from a US researcher. The US researchers had a limited French proficiency and the Ivorian researcher would occasionally pause to translate answers to English. We attempted to reduce social distance [45] from our participants by having one of the Ivorian co-authors lead the data collection. However since the foreign researcher sat nearby, this may have affected participants' responses. The data was primarily analyzed by non-Ivorian researchers (3 of US origin and 1 of Indian origin) but these non-Ivorian researchers regularly discussed the data and interpretations of emerging findings with the Ivorian researchers.

Fig. 3.2.: An interview session in a school in Adzopé .

PID	Gender	School	Class	Age	Career Aspiration	Smartphone
P1	M	Region-A	CM1	42	inspector	Y
P2	F	Region-A	CM1	39	counselor	Y
P3	F	Region-B	CP1	34	teacher (other than primary)	Y
P4	M	Region-B	CE1	41	counselor/college teacher	Y
P5	F	Region-B (2)	CP1	32	business	Y
P6	F	Region-C	CM1	33	college teacher	Y
P7	M	Region-D	CE2	54	private school owner	Y
P8	F	Region-D (2)	CE1	39	counselor	Y
P9	M	Region-E	CE1	51	*primary teacher*	Y
P10	M	Region-E	CE1	37	NGO worker	-
P11	M	Region-E (2)	CM1	49	*primary teacher*	Y
P12	M	Region-F	CP1	35	counselor	Y
P13	M	Region-G	CE2	30	high school teacher	Y
P14	M	Region-H	CM2	37	literacy counselor	Y

Tab. 3.1.: This Table summarizes the demographics and aspirations of teachers in the Adzope region.

3.3.2 Data Analysis

Table 3.1 summarizes the demographic of our data collection session in May of 2019 and Fig. 3.2 depicts a typical interview session. Interviews were recorded, transcribed, and translated into English before they were analyzed by the authors. We coded the transcripts to identify low-level themes using the *aspirations-avenues-agency* framework [107, 110]. We synthesized the data by using an affinity diagramming [25] approach guided by this framework (*aspirations-avenues-agency*) to generate findings to answer our research questions.

3.3.3 Context

This study was conducted in two rural cocoa-producing regions in Southeast and Southwest Côte d'Ivoire (the Adzopé and Soubré region). These sites primarily have an agricultural economy based on cocoa and coffee, which has been the primary source of income of residents for decades [102]. French is the official national language of Côte d'Ivoire but there are nearly 70 local languages, including Attié which is widely spoken in the Adzopé region, as well as mother tongues for each tribal group [181].

Primary School Teachers in Côte d'Ivoire

Primary school teachers are selected through an entrance exam called DECO (Direct Competitions organized by the Examinations and Competitions Department or DECO) with eligibility criteria of secondary school completion. Upon, passing the DECO, teachers undergo an education program in a leadership institute called CAFOP (Centres d'Aptitude et de Formation Pedagogique) for 3 years where they are taught by teacher trainers. Trainers teach pedagogical methods and also closely mentor teachers through internships. Once teachers graduate, they receive tenure in a school [179]. A single teacher teaches all the subjects (e.g., maths, French, social sciences, humanities) for their class. The school is managed by a headmaster who often teaches a class of his own.

Teachers in Côte d'Ivoire have a rigid centralized curriculum and schedule which is followed by the entire country. The ministry offers a guidebook to support the teachers on a daily basis. The guidebook offers lesson plans (*fiches*) which help teachers conduct the lessons. The lesson plans have guidelines, as Participant 3 (P3) states "*There are cards that are established, there is a canvas, there is a methodology that must be respected to prepare the cards*". Additionally, teachers are encouraged

to adapt their lesson plan to create a *"learning situation"* or an environment for children to learn. Headmasters receive training in management and advising, so they also serve as official support for all the teachers.

Challenges in teaching

Although the centralization of curriculum planning brings uniformity to the education system, it widens existing inequalities in rural contexts, thereby increasing the burden on rural teachers. We observed that teachers in rural Côte d'Ivoire had similar challenges observed in other developing countries, such as poor student literacy rates, absenteeism, and working with large class sizes [57, 50]. Many teachers expressed that students had poor literacy skills and they were able to notice this in older students (e.g., CM1 or fifth graders). In fact, a recent evaluation by our team found that 50% of fifth graders in the Adzopé region cannot read an age-appropriate word [96]. Teachers are trained to deal with a class size of 30 students [140], but we found that teachers in rural contexts often have to deal with *large classes*, of more than 60 students. A large classroom also brings students at multiple levels of proficiency, making it harder for teachers to teach a class and give individual attention to students. Teachers mentioned that students are absent often making it hard for them to catch up with subsequent lessons.

3.4 Findings

We describe our findings categorized into sections on teachers aspirations, avenues taken by teachers for their professional development and teacher's agency in technology. Although these sections are interconnected, we have organized our findings to answer specific research questions and highlighted key themes to improve readability.

3.4.1 RQ1: Aspirations

In this section, we explain teacher aspirations and then proceed to individual findings in the subsequent sections.

Teacher Aspirations

We found that teachers' aspirations were in two categories of (1) community aspirations (or embedded [110]), for students evolution which emerges from their students and their teaching; and (2) personal aspirations for career progression.

Student Evolution: We found that teachers derived happiness in seeing their students evolve academically and professionally. Teachers had smaller goals concerning improved comprehension from students as P11 tells us "*This morning you saw that I was evaluating students. I'm happy because I know that at least 90 or 95% understood my lesson*". On the long term, teacher aspirations involved their students' professional success as P1 expresses that "*for the 12 years I've been teaching, the first students I taught, some have come out of nursing, some are police officers. When we see that it amazes us, we are happy*". This finding resonates with work from other contexts [178] where teachers mentioned that they were vested in their student's success.

> When students come back after 23 years and say, "Sir, you've taught us good values and good attitudes when we were children in primary school and those same attitudes have transferred to us, to our work, today". Such remarks make me happy. I do not wait for them to come and give me money, but just that they understand that the good attitudes I instilled in them allows them to live a useful life - [P11]

Teacher Growth: Teachers expressed aspirations to improve their teaching skills to support their class better. Although teachers undergo rigorous training before teaching primary schools, they expressed that often their training did not transfer well to their classroom practice [133, 57]. Teachers mentioned that to fulfill their aspirations for growth they tried learning from their peers and kept practicing for example, P11 talks about writing on the board.

> I write well on paper but I found it difficult to write on the board when I started. Today, when I see my writing, I feel it's improved but it could be better. So every day I practice writing different texts on the board to improve my writing. - [P6]

Career Progression: Teachers organically mentioned career progression when we asked them their personal aspirations for the next five years. Teachers expressed that they would like to advance to new roles in education with primary school being a stepping stone towards their long term aspiration. As P2 aptly summarizes"*Like any person, I would like to evolve in my career, that is to say, not just stay at the primary level. Personally, move on*".

Career Progression Conflicts with Teaching Role

We discovered teachers' personal aspirations by asking *where would they see themselves in five years's [198]*. Almost all teachers said that did not want to continue teaching in primary schools, as P14 mentions "*In five years, I will definitely not be a teacher anymore. Even if I'm in education, I'm not sure if I'm still going to be a school teacher*".

Teachers aspired to join positions they perceived to be better than their current role as a primary school teacher i.e., to high school, teacher trainers or inspectors. Although most teachers did not want to continue teaching in primary schools, majority of them wanted to work in other positions in education. To reach those positions, teachers mentioned that they need to qualify in competitive exams and they hinted that it was very difficult to succeed. In fact, all participants hadn't succeeded during their term (average of 12 years) but they hoped to qualify in the next five years. One teacher mentioned that he attempted the exam all his career but sadly he could not succeed, he has now accepted that he supported his siblings and takes solace that he made a difference in their lives.

> I tell you that from 1997 until today when I speak to you, there is not a year where I did not try at least two or three exams. Unfortunately, maybe I'm so stupid that it never worked. [..] We had to find someone to help the little ones. Now, I do not feel I have succeeded, but still, I was able to at least help two or three who give me satisfaction today. - [P7]

Some teachers (n=4) organically told us that they chose the teaching profession as a short term solution to support a family's financial crisis. For example, P11 mentions he was training to become a doctor but his family problems forced him to terminate his education halfway and switch to teaching " *I studied for two years in the Faculty of Medicine from 92 to 94 and because of the difficulties with my parents, I applied for a teacher's post*". Similarly, others mentioned that they tried multiple career choices that did not pan out so they ended up working as primary school teachers.

> I always wanted to help others. First, I opted for the army [..] unfortunately, it did not work. After that, I tried medicine to help the sick, but that did not work either, hence I became a teacher. So I say to myself that *I'm fine where I am, but I want to do more*. - [P14]

Therefore these factors tell us that **teacher's career aspirations conflict with their current role as a primary school teacher**. Similar to our finding, prior work

in Côte d'Ivoire found that teachers chose teaching careers to get out of unemployment or to transition to other career positions [140]. In context of professional development, teachers in Côte d'Ivoire have little or no incentive for attending these training sessions as documented by the World Bank [27], therefore it does not align with their aspirations to progress in their career.

Education Role Models Influence Teacher Aspirations

However, the sense of community among educators helped teachers find role models who influenced them to stay motivated towards their education career aspirations as well as inspired them to teach.

> Well, five years, the goal is to go up, to have promotions. As I said, there are people as role models who started in primary education, and today they are counselors, others are college teachers. So it's with this in mind, too, that I'm thinking of five as well - big promotion, with a promotional cost. - [P4]

To understand teacher role models and their influence, we asked participants about teachers they admired while asking them to mention specific qualities about these teachers that they admired. Almost all participants (n=13/14) mentioned that they had a role model in education, many (n=6) admired their colleagues and a few (n=3) organically mentioned that their role models led them to their current career.

We found that teachers not only admired their role models but **teachers drew inspiration from their education role models to advance their career as well as improve their teaching**. P8 expresses this well when she talks about her trainer in teacher education school who inspired her "*whatever you ask for, even if it does not concern teaching, she (trainer) answers. She explains so well that sometimes it makes you want to be like her. [..] She makes you want to teach*".

We found that role models were often teachers in the same school, school principals, counselors, and a few mentioned their parents. Our participants also talked about skills and qualities that they admired in their role models, which they tried to incorporate into their teaching. For example, P3 mentioned her role model was a colleague who proactively learned from his peers which led her to admire him and inspired her to do the same.

> This person (colleague) is always going to others(teachers) to learn [...] This way of doing this person I liked and it makes me try to copy the same thing every time, try to collaborate with the colleagues who have just arrived. - [P3]

In some cases, role models influence a teacher's career path, for example, P7 mentioned "*He's a gentleman who impressed me a lot. First, by his way of doing, his charisma and then by the way of teaching even, but he was a professor of Mathematics. (And) I became a teacher*". A few teachers mentioned that a parent who influenced their career choice. Some participants mentioned that although they admired their past role models, they were cognizant that today they need to adapt and grow beyond their role models, as P2 expresses "*It must be said that the generations are different. So, wanting to look like the model we estimated, it is not possible*".

Our findings replicate prior work that aspirations are *embedded* in the community as teachers derive their aspirations from their role models who are community members i.e. peers, superiors, or family. We also observe the *mutable* nature of aspirations as teachers express the generation gap between them and their role models. Additionally, as mentioned in developmental economics and ICTD, we found that role models play a major role in a user's aspirations [198, 71] but for teachers, they happen to be educators in their community.

3.4.2 RQ2: Avenues for PD

In this section, we give a brief context of professional development (PD) in Côte d'Ivoire and then discuss existing challenges in this environment. In the subsequent sections, we explain how teachers find avenues (or pathways) to overcome these challenges.

Challenges in Teacher Professional Development

Professional development is conducted as workshops for teachers to help them learn new pedagogical methods. Professional development workshops are held outside the village in peri-urban towns. Teachers are required to travel to these locations for a week and then return to implement the new method in their subsequent classes.

> It happened in the neighboring village called Ananguie, Our counselors have their offices there. So when there is professional development all the teachers go there [..] then we come back to practice what we have learned. - [P6]

Training sessions are lectures hosted by counselors for teachers of the same grade. School directors have similar training sessions but are trained on the administrative and leadership aspects of managing a school. Teachers mentioned that there could

be up to 80 teachers per training session. Teachers expressed that the lecture-style lessons make it hard for them to transfer their learning back to their classroom. P2 suggested that they could have practical lessons "*professional development is like class sessions or sessions in lecture halls. I want it to be a little practical*".

Upon completion, teachers are offered teaching material (documents) that are needed to implement the new pedagogical method back in their schools. Teachers use these documents to create a new lesson plan to implement their PD lessons. The lesson plan acts as a guiding tool but teachers acknowledge that they need further support to implement the new method correctly, as P10 expressed "*not that everything will be perfect, but at least you have a driver in front of you*".

Teachers expressed that the teaching material from PD is slow to transfer to rural areas. Since the class material and the lessons are centralized, teachers find it hard to adopt PD lessons without consistent availability of documents. Even when teachers receive documents, they lack adequate material making it difficult to implement it correctly.

> So our problem is the same as I said if there is no material, the current material does not follow the new program. When the material arrives, it comes late after we have started our classes - [P7]

Teachers expressed practical challenges to implement student-centric methods due to cultural nuances. Teachers mentioned that the Western nature of PD required teachers to alter their cultural values to implement it in their classrooms. In Côte d'Ivoire adults have a superior status to children and a student-centric approach conflicts with their social norm.

> Today, a child can sit on the table, even stand on the table. If it was the old way, you'd get upset [...] but now you say "Excuse me, come down". You are even obliged to ask the child for forgiveness. - [P6]

Proper implementation of pedagogical methods is overseen by counselors who supervise their region by visiting individual schools. Counselors are ministry officials tasked with mentoring teachers and supporting schools with the administration in a region. As P4 aptly mentioned "*this training is followed by class visits, that is, the counselors come to the class to follow how we put it into practice*".

During school visits, counselors observe teachers teach in their class followed by a feedback session. Teachers mention that the counselor critiques their teaching and directs them toward appropriate ways of implementing pedagogical methods. Teachers not only get feedback on their pedagogy but they also learn about their shortcomings in their use of support material, classroom management, and teaching

behavior. Teachers also mentioned that there is a self-critique (reflection) element to their feedback so teachers can articulate their shortcomings to explicitly to seek feedback from the counselor.

> He chooses certain subjects of the day which you have to teach, he then observes your performance. He will correct your inconsistencies, express what's wrong, express what you should do, how you should lead children so they understand better, and what material you used that was not good. That's why he comes and then, in the end, there is a criticism. First, you make your self-criticism to see if the lesson you have done is past. After that, he makes the criticism, and then he gives you advice on how to improve yourself. - [P3]

Counselors not only evaluate teacher classroom performance, teaching methods but they also foster teacher growth by mentoring and improving their teaching. As OP1 said "*I didn't have training in the APC system (teaching method). When the counselor came here, he showed me how to teach the lesson and gave me a supporting document*". Therefore **counselors are the human infrastructure [170] behind teacher professional development**. However, we found that counselor visit frequency varied by region, some regions often had received visits in a month while some had not received a visit in the academic year. In Ivorian contexts, teachers receive teacher training for an average of 2 days a year [96].

In summary, we discovered breakdowns in professional development due to teaching style, transfer of resources and cultural nuances. We also found evidence of tension between Ivorian culture and student-centric PD methods as observed in other developing countries [133, 50] and counselors are the human infrastructure [170] of PD. However, we found that teachers have a strong support system and are creating avenues to implement and access PD which we will discuss in the subsequent sections.

Teacher Solidarity

We found that teachers have a strong social bond which creates a sense of belonging. Their social bond leads them to perceive themselves as a family which P10 aptly said "*Now, socially, we are a family. We have friendships, we have a solidarity fund [..] which we use to support each other through joy and misfortune*". They use the solidarity fund for joyous occasions such as parties and during periods of misfortune such as sickness or death. Their solidarity fund is a physical reflection of their social bond, which helps them collectively handle professional and personal

issues. Teacher solidarity expands beyond the school level to a district level and beyond as unions.

> Now we teachers of Region2 have our union called the association of teachers Region2. So once someone is touched, it means that all of the Region2 teachers automatically are affected. - [P12]

This finding of teacher solidarity resonates with work in the South African context which discusses the spirit of *Ubuntu* [76] or the sense of oneness shared by the people in the region. We found that *Ubuntu* also exists in teachers in rural Côte d'Ivoire. Professionally, teachers use this solidarity to find role models to inspire them(as discussed in the earlier section) or to support each other when they do not have support from the administration.

Solidarity Supports Accessing Professional Development

Although teacher professional development has challenges, teachers' work around these problems by leveraging their solidarity. Teachers' sense of solidarity extends to support both personal and professional problems. Teacher solidarity is acknowledged by the administration. P11 (director) mentioned how his school teachers use their solidarity to fill in for a teacher when he is sick.

> The solidarity must be created between us because one person can be sick while school is in session and the children have the right to education. But at the same time, the teacher is also entitled to care, being sick, he can not teach. I as the team leader of the school make pedagogical solidarity so I can take his course and work until a certain time and then hand it over to another teacher. - [P11]

Professionally, teachers use this network to support each other when they do not receive visits from the counselor. When teachers need additional mentoring, they support each other by (1) passively advising each other informally, as P11 expressed this sentiment "*if I have difficulties in a subject or my perception of something, I approach a colleague and ask for help. We can help each other at this level*". (2) they actively seek help by critiquing each other by role-playing as a counselor in each other's classes.

> I can teach a course that may be in history, and the other teachers come to observe me. For example, they come to my class, and then note all the mistakes I make. After that, I do my self-criticism, and then they criticize me [..], my shortcomings and what to do next time so that it can go better. - [P6]

Teachers expressed the reciprocal nature of support i.e. teachers learned from each other irrespective of experience levels. Each level of experience had something new to offer i.e. more experienced teachers had field exposure and techniques which they had perfected during their tenure while new incoming teachers would bring new methods that they recently learned during their initiation. P6 summarized this well "*There are people who have 30 years of service who are there. Often, we go to them, but often by research, we who are new, we also teach some things to our deans, so it's reciprocal*".

We found that **solidarity helps teachers find alternate avenues to access professional development**. This finding helps us learn about existing networks of support among teachers which originates from their strong sense of belonging. The sense of community highlights the community spirit of Ubuntu [76] that exists in the South African context, our work shows how this phenomenon is present in teachers of Côte d'Ivoire and how it influences teachers handle breakdowns in PD. Lastly, our finding supplements teacher co-learning as observed in Western settings by Clement *et al* [40] which we found to exist in the rural context of Côte d'Ivoire.

Teachers Create Avenues to Implement PD

Teachers of Côte d'Ivoire have challenges in PD implementation as discussed earlier, however, they find workarounds or avenues to handle these challenges. Teachers have a rigid centralized curriculum but they have the freedom to contextualize their lesson plan for their classes. Teachers prepare their lesson plans at home and they acknowledge class preparation to be an integral part of teaching. As P8 mentioned " *The most important thing is to prepare my classes at home, read, understand before you come to class. That's what makes you a good teacher*".

(1) Teachers mentioned that they **prepare lesson plans** by supplementing the centralized guideline with relevant content for their classes. They expressed that it is cumbersome to search relevant material for adapting lesson plans for rural students, mainly because the students are below the expected centralized literacy levels.

> We prepare our cards (lesson plans) at home by preparing for the lesson you teach, there is a guideline that will show you how to do it for your student's level. You try to adapt the card to the level of your students during the preparation. If your children are high, you try to raise the vocabulary too. Now, for the students of the village, it is difficult to use the complex vocabulary, so it is necessary to tailor it to their level - [P3]

Additionally, teachers mentioned that students' home environment affects learning at school. For example, students in rural contexts are more accustomed to interacting in their native language (like Attie) at home rather than French, leading to lowered fluency and literacy. As P10 told us "*We are in a rural area. French is not easy for these children. They speak more in their dialect*".

(2) Since Côte d'Ivoire is multilingual, teachers often face scenarios where they are unfamiliar with the local language spoken by the students and might not be able to communicate with them. However, teachers mentioned that they use **students as resources** to work around this issue to implement their lessons. Teachers use knowledgeable students in the class to play the role of translators to help them teach to students of low French proficiency.

> For example, when I say "a mountain" in French, students do not understand. So I ask students, as we are in an area of Attie. "In Attie, how do we say mountain?" He who understands mountain in French says: "In Attie, we say like that". And then the others say "Aaah! What we have just said here, in French, is called a mountain." - [P10]

In our class observation, we also saw that the teachers use older students as teaching assistants to manage the classroom. Teachers also mentioned that they manipulate seating arrangements based on student proficiency to support peer learning. Additionally, we observed a teacher using peer grading among students as an initial evaluation of a test. P14 explains that it's his own idea to distribute the notebooks randomly among students to grade their peers so they learn.

(3) Teachers are trained to deal with a class size of 30 students and are taught to implement their lesson plans for the same, however, they often had to work with large class sizes. As P9 stated "*when you find yourself with 100 students, it becomes an audience. It's not a class anymore. You speak in noise and it is not easy*". Additionally, large classrooms also lead to students of multiple learning levels in the same class i.e. a class can have advanced students who find the material less engaging and lower level students who need additional support. Teachers mentioned that they manage their class using **creative teaching methods**. Teachers implemented their lesson plan to help lower level students by using music, technology, songs and stories to engage students. P10 expressed that he takes a playful approach of shouting like a bird when children are distracted.

> When I feel that students are distracted, I imitate the cry of an animal or a bird. I say "Ouhou !!!". Then they (students) repeat after me. They see this as a game, so it relaxes them. - [P10]

Teachers face contextual challenges of inappropriate content material, low student literacy, and large class sizes. However, teachers find avenues by preparing lesson plans, leveraging students as resources, and by creating new methods to engage classes. Although teachers feel that these methods are useful, it is unclear if they are improving student learning outcomes. A study in the region found poor literacy rates among primary school children [96], which suggests there are opportunities for channeling these avenues to improve student learning. Additionally, teachers mentioned that technology played a role in helping them prepare for a class or implement a lesson plan.

3.4.3 RQ3: Technology Agency

This research question is focused on understanding teachers use of technology for professional development. Our focus was on information technology i.e. devices (smartphones and laptops) and common applications used by teachers. We were interested to learn how teachers build agency towards PD using technology.

Teachers' Perceptions of Technology

We found that all teachers had exposure to smartphones and almost all(n=13/14) currently owned a device. They used it for using social media, playing games, and sharing media using Bluetooth services like Xender [223]. WhatsApp and Facebook were the prominent applications used among teachers, matching the global usage statistics of these applications in the developing countries [216]. For teaching, they used dictionary applications to find the meaning of words, conjugation, or searched on Google to find content for their lesson plan.

Teachers expressed a positive attitude towards technology and its benefits to education. They saw technology as a positive force connected with evolution, as P10 aptly summarized " *I think technology is a very good thing. Normally, all schools should have computers. As the world evolves, I think schools too must evolve for education to evolve*". This positive attitude towards technology is similar to perceptions of teachers in India [203]. However, participants expressed that they were concerned that technology for students needed supervision to benefit their learning.

> Generally, what I dread is that, when you give someone a tool (technology), he automatically sees the playful side and that's a bit dangerous. However, if we manage to channel the tool, it's very good - [P7]

Teachers used technology to address this concern by channeling children's curiosity for technology to engage them in their lessons. Technology supports them to deal with classroom challenges such as managing large class sizes.Therefore, **teachers find avenues using technology to tackle contextual challenges** i.e. teachers use technology in non-traditional ways to discipline and captivate their students towards learning.

> Children are captivated by my laptop. I do not know if it's the color or the screen that makes them follow better. When I use my device, they feel more comfortable and they understand better. So if someone talks, I do not use it. We know that at least there is a student who will disrupt the class, I say "as you chatted, we will not use the computer today." -[P6]

Outside of class, teachers used computers to print documents to manage student's scores or printing their lesson plans. Few teachers mentioned that they were encouraged by the ministry to use technology to prepare their lesson plan and they were open to using it more if they had official orders.

Teachers Use the Internet to Prepare their Lesson Plans

Teachers mentioned that professional development is implemented by preparing a lesson plan before class. Although they had preparation material, they expressed that it often does not match the updated curriculum or the tailor to rural students. Therefore, teachers may spend hours searching through various documents to find appropriate content for a lesson plan.

> We have the old FPC (old method) documents with us, while the course content uses a competency-based approach (new method). Do you see it? [..] So, today to do a 30-minute course, you can easily spend three hours searching through documents for the content. - [P7]

However, we found that teachers take ownership of this problem and use the internet to help them find appropriate resources for their lesson plans. As P11 mentioned "*I am obliged, as a teacher, to search on Google. I either do my research there or I need to use the old documents*". Teachers expressed that they either used their smartphone or their computer at home to do internet research. Although they are able to leverage the internet, they also mentioned that it is necessary to adapt the content to support the rural students.

> I research using Google for more information and how to better run the course so students can understand. We call this learning situation. I first read a short text orally so that students are centered and captivated in the lesson. They are curious to know the rest of the story so they continue to listen. - [P6]

Although they find value in using the internet, they expressed that this process is cumbersome and it is not easy to use technology, as P6 mentioned "*Often, while of searching (on the internet), we have migraines*". However, teachers voluntarily chose to spend this additional time after school to find content because they believe this will benefit their students in the long run. Teachers also mentioned that although it is difficult at first, they eventually get better at research and even use their expertise to teach their superiors. P6 summarized this well "*Often by research, we who are new, we also teach some things to our deans*". Therefore, **teachers use technology to build their agency for implementing professional development** to support students' learning.

Using technology to work around the challenges in professional development is an expression of teacher *voice* [129, 117, 2] against the difficulties in their context i.e. lack of documents and appropriate material. This phenomenon opens opportunities for amplifying and connecting teacher voices [10] to reach higher administration thereby creating a social change in teacher professional development.

3.5 Discussion

In this section we briefly discuss reflections on our aspiration-based approach, which leads us to open questions. We then propose some design recommendations for answering these open questions and conclude with limitations of our work.

3.5.1 Reflections on Aspirations-based Approach

Our research helped us understand teacher needs and aspirations in the context of Côte d'Ivoire. We found breakdowns in teacher professional development which helped us understand their need for mentoring (frequency of visits), contextual support (for rural students), and access to resources (PD documents). However, by understanding aspirations, we learned that teacher aspirations for career progression conflicts with their role as a primary school teacher. The pathway towards achieving their aspirations is through individual performance in competitive exams which does not involve the community (students or peers). Therefore designing

technology to address professional development needs alone limits its impact on the teachers as predicted by Toyama [198]. Although technology can play a role in career progression to provide access to mentors or resources, it's ultimately up to the teachers to build their capacity to use these resources to achieve their aspirations. Social impact for teacher PD is possible when career aspirations align with their role i.e. teachers are incentivized towards their career progression by teaching better, educational outcomes or attending PD. However, technology can be channeled to act as a catalyst towards influencing policy by amplifying teacher voice. We also observe how a community influences aspirations (or aspirations are embedded [110]) when teachers derive inspirations from their role models or have aspirations for their students. Therefore these community aspirations can be leveraged to motivate and support teacher PD.

We acknowledge that we have scoped aspirations to a teacher's profession but similar scoping has been done by others [26, 110, 165]. More research is needed to understand deeper levels of career-related aspirations, non-career related aspirations, and creating a hierarchy of aspirations [198]. Although we explored aspirations in our work, it is unclear how to channel teacher aspirations towards social change with technology. Furthermore, it is unclear how to balance career and community aspirations or even measure the developmental impact on the aspirations of teachers. We provide some ideas to design technology-based interventions to answer the questions above.

3.5.2 Design Implications

We found that a high percentage of teachers had access to smartphones, therefore smartphones can be a medium of design. Designers interested in creating sustainable interventions can draw upon an asset-based approach [147] to leverage existing assets (i.e. smartphones) and applications popular in the context e.g. we found that teachers used WhatsApp, Facebook Messenger, and Google in Côte d'Ivoire. However, we also found that teachers are still learning to use their smartphones. Therefore designers need to be mindful that any new design will need a shallow learning curve so teachers can adopt it. Alternatively, designers can incorporate training when they deploy their technology [85]. As an example scenario, consider a chatbot on Facebook Messenger that mentors teachers on PD. This scenario uses existing technology and has a low learning curve as teachers are familiar with it. We will use this scenario as an example in subsequent sections.

Balancing Career and Community Aspirations

We know that teachers' career aspirations conflict with their current role as teachers i.e. their professional success criteria do not intersect with children's success. Therefore technology design needs to focus on balancing both career and community aspirations to create a social change in teacher professional development. Our data suggests that role models (colleagues, counselors, inspectors) play a dual role to inspire teachers in their career aspirations as well as motivate them to improve their teaching. Prior work used role models in a documentary to demystify the path to financial independence [190]. Hence designers can use such interventions with relatable role models to inspire teachers towards their career progression while showing examples of good teaching practices. Designers can use role models for best practices using multimedia such as video [7] or audio [116]. Such multimedia can also act as tutorials to change behavior to help teachers adopt technology into their curriculum. However, care must be taken to focus the role models in the primary school domain so teachers are motivated to improve themselves in their schools while being inspired to advance their careers. Using our chatbot scenario, teachers can be shown videos of role models performing a teaching method to inspire them to implement PD methods. Additionally, the same role models can talk about their success stories and strategies motivating teachers towards their career progression.

Measuring Impact on Aspirations

Prior work on measuring the economic impact of aspirations [118] used a self-efficacy scale to measure the perception of the user's agency. Since the agency is built towards achieving aspirations [107], measuring perceived agency can help understand a user's present circumstance towards their aspirations. Therefore researchers interested in designing and measuring teacher aspirations can utilize self-efficacy scales to measure the impact of their interventions on teacher's perceived agency (or self-efficacy). Prior work in a controlled environment found that building teacher computer self-efficacy could influence teacher self-efficacy in PD [59]. Therefore designers can extend this research to learn about teacher aspirations and technology in a long term field setting for PD. Additionally, researchers can create custom scales to focus on individual aspirations i.e. student evolution, teacher growth, and use self-efficacy to measure the impact or relationship between each aspiration. Using our chatbot scenario: if the goal of the project is to improve student learning, then a customized self-efficacy for student evolution can be used to evaluate the intervention.

Designing for Social Change using Feminist HCI

Although we learned about teacher aspirations, it is unclear how to channel their aspirations towards a social change. To bring about a social change, we recommend a Feminist HCI [19] approach towards supporting teachers with their professional development. The feminist HCI approach is inspired by feminism and provides guidelines for designers to balance societal problems while preventing marginalization of social groups (in our context teachers). Feminist HCI (through pluralism and participation) suggests different users (teachers) need individual support therefore there is no universal design. Therefore designers can learn from these ideas to provide personalized [39] and adaptive technology [99] to support individual teachers. Using our Messenger chatbot scenario: Artificial intelligence could be used to provide personalized support to teachers with each teacher having individualized support.

Teachers have strong solidarity to support each other and this phenomenon can be leveraged to build online forums to expand their support network. These forums can provide pathways for teachers to seek mentoring, acquire role models, or express their *voice*. We found that teachers express their voice against challenges in the context by inventing new methods and finding innovative uses of technology for their PD. Designers can channel these activities towards amplifying community voices for social change [10]. To promote a social change, designers can leverage the concept of advocacy (from Feminist HCI [19]) to allow political expression. To allow teachers to have a political voice, designers can include administrators i.e. directors, advisors, and ministry officials [41, 116] who can draw insights from communal phenomena to make official decisions. Using our Messenger chatbot scenario: a summary of teacher challenges surmised from chatbot interactions can be sent to the regional advisor to prioritize his visits to mentor teachers.

3.5.3 Limitations and Future Work

We conducted our research in two regions but we focused on aspirations only in one region. Future research can address if teacher aspirations vary by region. Secondly, although teachers have a social bond it is unclear if this bond transfers to a technology media. Participants mentioned that an unofficial Facebook group for teachers exists in Côte d'Ivoire but some said they weren't active users because they preferred in-person communication. Therefore, future work can learn about social media usage by teachers and understand how much of their social interactions transfer online. Although we did not specifically ask for career aspirations, teachers organically mentioned that they would like to change their career in the next five

years. We expect there could be an availability bias as preceding questions in the interview were on their professional life. Future research can focus on encouraging participants to discuss deeper levels of career aspirations or alternative ones such as having a family, building their own house or achieving fame.

3.6 Conclusion

Teaching is challenging in rural contexts in developing countries because of contextual challenges that lower teacher motivation and educational outcomes. Teacher motivation and educational outcomes can be improved by teacher professional development programs but these programs are limited by poor infrastructure in rural areas. Although infrastructural challenges can be overcome by information technology today, it is unclear how such technology can support teacher training. Therefore to explore opportunities to promote social change in teacher professional development in low resource contexts with technology, we conducted a qualitative study with 22 teachers of rural Côte d'Ivoire by following an aspiration based approach. Our finding reveal that (1) teachers aspire to achieve higher posts in education which conflicts with their current role as a primary-school teacher; (2) teachers have a solidarity which helps them (a) find role models for their career and teaching, and (b) tackle breakdowns in professional development; and (3) teachers also take ownership of their professional development by finding workarounds by inventing new methods, taking student support and using the internet to prepare their lesson plan. Based on these findings, we discuss design directions for balancing teachers' community and personal aspirations, ideas to measure aspirations and provide implications for designing for social change in teacher professional development.

Study 2A: Initial Design

4

4.1 Overview

Fig. 4.1.: The goal of study 2a was to explore the feasibility of a conversational agent to support rural teachers. I derived from study 1 that teachers used smartphones and were already using them to support their work.

The previous chapter described teachers' smartphone usage in rural Côte d'Ivoire. I learned that teachers had challenges in professional development but used smartphones to support their classroom teaching. In this chapter (refer Fig 4.1), I describe the initial designs of a conversational agent to support teachers in pedagogical programs. Prior work in conversational agents has shown promise to support scalable interventions, but it is unclear how to translate such interventions for teachers in places like rural Côte d'Ivoire. Therefore, I built *DIA* a conversational agent to scale expert knowledge and support localization. I chose *DIA*[1] as a it is short for DIA-logue flow [49] by Google, which was used in the earlier version of the system. The later iterations of *DIA* uses Rasa [138] an open source framework.

This chapter(refer Fig 4.1) addressed the following research question.

> **RQ1:** What is the feasibility of a conversational agent (*DIA*) to mentor teachers in low resource contexts like rural Côte d'Ivoire?.

[1] *DIA* (pronounced as *diya*) also means lamp in Indian culture, which is a symbol for light and positivity.

Fig. 4.2.: A participant interacting with *DIA*. We deployed *DIA* as a WhatsApp Assistant in rural Côte d'Ivoire for 4 weeks to mentor 38 teachers.

4.2 DIA

Therefore, we developed *DIA* a human-chatbot (humbot) hybrid system to design chat-based interventions for low resource contexts. Our tool is a human chatbot hybrid designed to scale expert knowledge. We designed it for social media to improve sustainability and to allow local-language interaction to support emergent users. Users interact with the system using social media messaging platforms such as Facebook Messenger or WhatsApp. An NLU (Natural Language Understanding) engine parses user response and returns a response from the appropriate module of (1) Automated intents, (2) Knowledgebase or (3) request help from an expert.

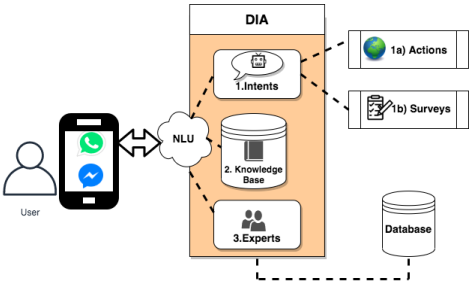

Fig. 4.3.: Shows the architecture of *DIA* consisting of (1) Intents of automated interactions (2) Knowledge base of curated questions (3) Experts who interact when 1 and 2 fail to provide an appropriate response.

(1) **Intents** consists of simple pre-built conversations for engaging in small talk (such as greetings, introductions, jokes). These pre-built intents are triggered upon a keyword or a specific command for e.g. *Tell me a joke*. Another set of intents is dynamic and ideal of task-specific conversations. Task-specific conversations are classified into two modules of actions and surveys.

- (1a) *actions* which are scripts tasked with local computation (e.g. dictionary, calculator) or fetching information from the internet (e.g. Wikipedia). This

information is parsed and returned to the user with an excerpt and a link if applicable. e.g. (*What are the citations of Kant?*)

- (1b) *surveys* that can be used to gather qualitative or quantitative data from the user by asking sequential questions. The survey module can also be used to send information with text or multimedia (videos, audios, or pictures) to create a human conversation. e.g. (*In which school do you teach?*)

(2) **Knowledge-base** is the database of content-specific questions that form the core curriculum of the chatbot interactions, they are curated by seeding the chatbot with data initially or by dynamically building from the database by interactions with experts. e.g. (*How to Implement TaRL?*)

(3) **Experts** form the final source of content when the chatbot fails to assign appropriate automated response. Our system gives the user a choice to request help from an expert, following the HCAI principles [6] e.g. (*I am sorry, I don't know the answer to this, would you like me to ask my superior and get back?*)

All the data is stored in the database to add expert interactions to the knowledge base and improve the agents' linguistic capabilities. Therefore over time, expert knowledge can be populated to the database leading to more automated and natural interaction. The interactions described so far have been user-initiated.

DIA can initiate interactions by sending personalized bulk messages [153, 46] to the users which can be used to trigger conversations or conduct surveys. The survey questions are monitored by the administrators who can add or remove questions from the dashboard. The qualitative and quantitative data collected from user surveys can be used to collect insights about the community. Lastly, the system can also detect the *read status* of the user to understand internet usage and different forms of user engagement.

This study is part of an ongoing research program on supporting literacy in cocoa farming communities in rural Côte d'Ivoire. This project aims to improve child education through poverty reduction and improved educational quality. Educational outcomes [78, 70] can be improved by teacher training but implementing such interventions in rural areas is challenging due to infrastructural issues and *lack of available teacher trainers* [24, 90]. Recently in Côte d'Ivoire, a new teacher training method i.e. Teaching at the Right Level (TaRL) has been implemented by the TaRL Africa team [193] in collaboration with the Ivorian Ministry. Prior research has shown the success of this teacher training method in Indian and other African contexts [16, 192]. This project is a collaboration with the TaRL Africa team to learn the feasibility of *DIA* to mentor more teachers in the teacher training method (*NewMethod*) with technology. We conducted a pilot study in *Méagui* a rural area of Côte d'Ivoire during the *NewMethod* implementation session

of January 2020. The research team introduced the teachers to the WhatsApp assistant during the *NewMethod* training classes and we instructed teachers to chat with the assistant to seek support with *NewMethod*. We also told the teachers that the chatbot can answer questions outside TaRL but our system will prioritize answering questions related to *NewMethod* and teaching. Teachers were not given any incentive to interact with the chatbot. We conducted the study for 4 weeks to answer the following research question.

RQ: What is the feasibility of a conversational agent (*DIA*) to mentor teachers in rural contexts in low resource contexts like Côte d'Ivoire?.

4.3 Field Deployment

To conduct a preliminary evaluation of our system, we received IRB approval from the University of Delaware (protocol *1478038-1*) and we deployed *DIA* on WhatsApp to mentor 38 teachers in the rural context of Côte d'Ivoire for 4 weeks. The system was developed using Flask [61] (a Python framework) and Twilio [@201] to support interactions on WhatsApp. We used DialogFlow [49] for basic intents (i.e. for small talk, jokes) and writing custom functions in Flask for complex intents (i.e. Wikipedia, conjugations, calculator). We built our knowledge base using the TaRL manuals and we used cosine similarity to match the appropriate response. Lastly, we built a dashboard where researchers played the role of experts and answered questions referring to the manual on the teaching method [191] and Google search for complex questions.

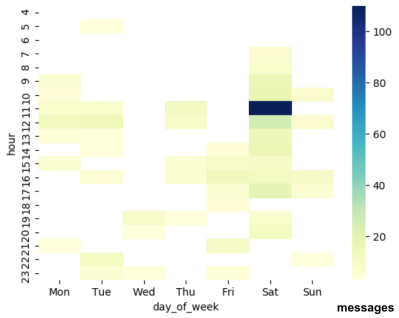

Fig. 4.4.: This figure shows the cumulative usage of *DIA* by the teachers every hour. We see that teachers use the system on Saturday afternoons or after school hours.

We deployed the bot for 4 weeks and learned about the feasibility of using *DIA* for supporting teachers in rural Côte d'Ivoire. Teachers were encouraged to use the system whenever they needed support with teaching and there was no incentive

provided for using the chatbot. Teachers interacted on a total of 2132 messages (930 from users), more than 98% of the conversation used accurate French words (indicating teachers usage of autocorrect). Although we intended the bot to be teaching method focused, we received a total of 97 questions related to education, football, current affairs, health, and finance.

The Fig.4.4 above shows the usage of the chatbot for 4 weeks. Teachers communicated most with the chatbots on Saturday afternoons, during their breaks (12:30-2), or after class. We inferred that teachers do not have access to the internet daily through message delivery logs. We also conducted chat-based surveys about the teaching method and sent motivational messages to the teachers. We observed that all 35 teachers answered the initial entry survey of 8 questions, 32 (91%) teachers answered 12 follow up questions in the first week and 12(34%) answered all questions by the end of 3 weeks with approximately one reminder a week.

4.4 Discussion

Our current implementation had some workarounds to function smoothly on WhatsApp. Firstly, WhatsApp API [215] restricts free-form interaction with the user in a 24-hour session, beyond which only template greetings (e.g. *Your code is XYZ*) are allowed to be sent to the user. Since the pre-approved templates in Twilio [@201] were in English, we added a French question after the English template which may have led to low survey feedback from the teachers. Secondly, we had to break a few conversational guidelines [72] for designing chat interactions to speed up prototyping (*press 1 for contacting an advisor* while chatbot design guidelines suggest that conversations with agents must be natural). For future work, we intend to fix this limitation by contextualizing the chatbot conversations for local contexts through Wizard of Oz [42]. In our pilot study, our research team answered questions which the chatbot could not answer as this study was intended to understand the feasibility of the intervention. In the next phase of the project, we plan to provide opportunities for administrators to support teachers mediated by the chatbot similar to prior work [197]. Additionally, we acknowledge that our system although intended to support the design of chatbots for emergent users in developing contexts has been piloted in a rural context. We expect more research is needed to understand the feasibility of *DIA* in other emerging economies in Latin America or the Caribbean. However, we expect our work has given a platform for future researchers to leverage our system to design chatbots in developing contexts.

We see opportunities to extend *DIA* using Crowd-AI architectures like Evorus [86] to seek support from novices to automate meaningful conversations to reduce

the load on experts. In addition to using the architecture, research can learn from novices instead of crowd workers to use voting for content moderation like Sangeeth Swara [206] and content generation like Avaaj Otalo [143]. Such systems can also be used to build a crowdsourced corpus of languages with fewer data sets [163].

Furthermore, *DIA* can be used to expand research on microlearning in developing contexts by utilizing Intelligent tutors [113] on social media. The Knowledge-base from *DIA* can be used as a question bank to test users through multiple choice questions or short answers. Multimedia can be used to provide enriched content such as GIFs or short videos to create engaging conversations and questions [183]. Additionally, short and progressive incentives can help users stay motivated to complete the lesson and to cover their internet costs [189] or provide them with an additional source of income [208].

In summary, we observe from our preliminary deployment that *DIA* is feasible to mentor teachers in low resource contexts like Côte d'Ivoire. *DIA* helped us collect a database of topic-specific questions from teachers and understand the unique mobile phone usage of teachers in rural contexts. We learned that teachers use autocorrect in French through chat logs and teachers use the internet on their smartphones intermittently during the week through message delivery logs. We were also able to collect teaching-related survey responses from teachers. Although all teachers answered the first 8 questions, only 35% of teachers answered all 20 survey questions. We see opportunities for building on this research to design chatbot based interventions for the developing world.

Study 2B: Design

5

> *"We dream of climbing the ladder, to get there, we have to do our job better".*
>
> — **D1**
> Designing for Teacher Aspiration

5.1 Overview

Fig. 5.1.: The goal for study 2b was to extend theory (aspiration) to technology (conversational agent) designs to support teachers with pedagogical programs.

Study 1 explored teachers' smartphone usage and their aspirations in rural Côte d'Ivoire. I learned that teachers use smartphones to support their classroom teaching and address challenges in professional development. Although prior work has used smartphones to support teachers, it is unclear if chat applications like WhatsApp–which many teachers worldwide use–can help teachers sustainably in rural Sub-Saharan Africa with low internet infrastructure. Therefore, in Study 2A, I built and evaluated *DIA* a conversational agent to scale expert knowledge. I learned that such designs were feasible to support teachers' early system deployment [31]. Additionally, in study 1, to extend aspirations theory to conversational agent designs, I discovered that teachers aspired to benefit their students through teaching and progress in their career hierarchy to become trainers. However, it is unclear how these teacher aspirations intersect with new implementations of pedagogical programs.

Thus, in this chapter(refer Fig 5.1), I explore this design space for pedagogical programs, teacher aspirations, and conversational agents in low resource contexts. In study 2B, I conducted two related studies to examine the use of such technology in this design space. The first was a qualitative study with 20 teachers and ministry officials in rural Côte d'Ivoire to understand opportunities and challenges in technology use for these stakeholders. Second, I used our data from Study 2A as a conversational agent probe over WhatsApp to uncover realistic use cases from these stakeholders. In this chapter, I address the following research questions:

5.2 Research Questions

RQ1a: Given prior findings on the limitations of connectivity and infrastructure, what are the opportunities and challenges for technology to support teachers' implementation of a new pedagogical program in low infrastructure contexts like Côte d'Ivoire?

RQ1b: Based on their use of a technology probe, how do teachers engage with a technology like a conversational agent?

Finally, to explore sustainable designs using a theoretical lens on aspirations, we investigate:

RQ2: How do teachers engage with the implementation of a new pedagogical approach in rural Côte d'Ivoire?

5.3 Study Design

This study is part of an ongoing research project to improve children's education in rural Côte d'Ivoire through poverty reduction and improved education for rural cocoa farming communities. An interdisciplinary team from Ivorian and North American universities conducted this study in partnership with the Ivorian Ministry of Education. We received approvals from all our institutional boards (Carnegie Mellon University protocol *STUDY2019_00000510*) and the Ivorian government to conduct the study.

5.3.1 Site Description

We conducted the study in a southwest region in Côte d'Ivoire. French is the official language of Côte d'Ivoire, but there are nearly 70 local languages [181]. This site primarily has an agricultural economy based on cocoa and coffee, which have been residents' primary source of income for decades [102].

The study site is a rural farming town in the Soubré region. It has a few urban schools inside the city, while the remaining rural schools are distributed in communities away from the city. Communities situated away from the city have lower infrastructure: i.e., they lack adequate water, electricity, and telephone signal. Remote communities have poor road conditions, which further impedes travel and increases their isolation. Students in these rural communities have low literacy rates, influenced by the rural context and low infrastructure [121, 120] [1].

A year before the study (2018-2019), the site hosted a new pedagogical program (*NewMethod*) to improve students' foundational math and French skills. The program found successful improvements in students' skills in initial pilots. These initial successes inspired the NGO to scale the program to many schools in the region.

5.3.2 Background on *NewMethod* and Teacher Training

The *NewMethod* program is a teacher training program implemented by an international NGO. This program aims to improve foundational math and French of 3rd, 4th, and 5th-grade students. Teachers first perform a baseline test to split the students into three groups by their learning proficiency. Throughout the year, teachers conduct activities with these groups of children in dedicated 45 mins slots every day for French and mathematics skills. These activities are child-centered and playful to deliver instructions at a skill-appropriate level. Teachers test the students again during the middle and the end of the year to evaluate the student's progress.

The *NewMethod* program is embedded in the Ivorian education system and utilizes the stakeholders in the ministry to implement and monitor the intervention.

Teachers form the main stakeholders. *NewMethod* uses 3rd, 4th, and 5th-grade teachers to implement the activities. The *NewMethod* program encourages teachers to play the role of facilitators. *NewMethod* activities use hands-on games to teach foundational skills to children.

[1] **Note**: More details about typical school setting and teaching can be found in our prior work [33] in section 3.3.1

Fig. 5.2.: A typical *NewMethod* activity in a rural setting. Students are split into levels based on proficiency in French and math. At each level, they participate in participatory activities for 45 mins a day for each subject led by their teacher.

Directors are senior school teachers appointed by the inspector to manage the school. Directors act as the first line of support for the teachers for *NewMethod*; they receive special mentorship training and coordinate the *NewMethod* activities in the school.

Pedagogical advisor is a remote mentor who visits schools and provides teachers with professional development support. For *NewMethod*, pedagogical advisors visit schools to observe teachers perform *NewMethod* activities and guide them to implement the method correctly.

Inspectors serve as administrative and pedagogical supervisors for the region. Inspectors visited schools to observe teachers implement *NewMethod* and motivated them.

Master trainers are high-ranking ministry officials specializing in pedagogy. Master trainers supported the teacher training and visited schools to observe the teachers.

Teachers receive training for *NewMethod* in week-long workshops before implementation. These workshops are held at a school near the city; most rural teachers temporarily stay in the city to participate in workshops. Our research team started the research project during the *NewMethod* training workshop at the study site in February 2020.

Tab. 5.1.: Summarizes our data sources collected by the team

Observations	
Participants	∼70
Duration	6 days (9AM - 5PM)
Stakeholders	Teachers ∼60, Directors: 4, Master trainers 2, Advisor: 1
Timeline	(Week 1) - during *NewMethod* training
Surveys	
Participants	37
Gender	Female: 9 Male: 28
Stakeholders (4)	Teacher: 28, Directors: 6 Advisors: 2, Inspector 1
Timeline	(Week 1-3) - mostly during training
Interviews	
Participants	20
Gender	Female: 3 Male: 17
Stakeholders (5)	Teachers: 10, Directors: 4, Official: 6
Schools (4)	Urban: 1, Rural 3
NewMethod Observations	10 hrs
Subjects	CP1-CM2 (3rd-6th grade)
Timeline	(Week 1-3) - after training
Conversational Agent Probe	
Participants	38
Duration	14 weeks
Timeline	(Week 1-14) - after training, till the end of the academic year

5.3.3 Data Collection

Our data collection team consisted of a US-based HCI researcher and a linguistics graduate student from Côte d'Ivoire. The data collection was conducted in French by an Ivorian researcher with help from a US-based researcher with moderate French proficiency. We described the study and the purpose of our visit during the welcome keynote session. The Ivorian researcher verbally explained the research and the protocol risks to each participant before collecting data. The Ivorian researcher obtained individual participants' oral consent as appropriate in the context. Study participation was voluntary, and participants were not compensated for any method.

We collected data for three weeks through observations, surveys, and interviews. We also deployed a conversational agent probe to 38 teachers to learn technology use cases to support teachers. Table 5.1summarizes the data collected from these various methods.

Field Observations

NewMethod training involved about 60 teachers from selected schools in the region. The teacher training had a tight schedule from morning to evening, with a few short breaks and a lunch break in the afternoon. Directors and pedagogical advisors led the program and frequently selected a teacher from the group to guide the activity. A selected individual role played as a teacher implementing the activity, and the rest role-played as students. After a few mock sessions, there was a question-answer session where the teachers answered questions raised by their peers. Often when a question was challenging, they would ask the directors or master trainers. To support inexperienced teachers, directors assigned tasks such as note-taking or leading activities to increase their involvement. Although the training was rigorous and formal, directors lightened the mood by occasionally introducing informal activities like singing and dancing.

The research team observed and participated in the activities throughout the week. These observations helped us understand the *NewMethod* program and the various classroom activities implemented by the teachers. We were able to glimpse the situated struggles (sitting on the floor for long-duration, heat) and bonding experiences (singing, dancing) during this challenging week. We recorded our field notes and discussions in our research journal and used these lessons to refine our questions for our surveys and interviews. *NewMethod* observation data is used for RQ2 5.4.3.

Surveys

We used a Google form in French on a tablet to conduct surveys. The surveys had questions to understand participants' technology and social media usage, demographic questions, and questions related to *NewMethod* to get initial perceptions of teachers. Responses helped us structure our interview protocol. Fig 5.3 depicts a survey session in a school where the interviewer is helping the teachers. Survey data is used for RQ1a 5.4.1.

Participants were given the tablet device and encouraged to complete the survey independently. Participants often requested help navigating the sections of the Google form and requested clarification for specific questions. The surveys took approximately 30 mins. Thirty-eight participants responded to the surveys (29 teachers, 6 school directors, and 3 advisors). Most survey responses were recorded during breaks or after the teacher training sessions. We also collected additional responses from participants during interview sessions if they hadn't attempted it before.

Interviews

Fig. 5.3.: The researcher helps a teacher with a survey (left) and the researcher conducts an interview in a school (right).

The week after the training, the research team observed baseline tests and the first week of the *NewMethod* activities. We collected photos, videos, and a diary of events and had various discussions offline to understand the training teachers' perspectives. We also interviewed teachers during these observations to get contextual information about the program.

We chose four schools (one urban school and three rural) after discussions with the pedagogical advisors and master trainers. Schools were chosen to observe *NewMethod* in different locations and interview the stakeholders to get a holistic understanding of *NewMethod* at the study site. We interviewed the director and 2-3 teachers for every school based on their availability. The interviews were conducted with voluntary verbal consent from the participants, and they were offered no compensation for participating. Individual interviews of between 1-1.5 hours were performed, with our field team conversing personally with ten teachers, four directors, two advisors, and one inspector. We also report data from our discussions with three master trainers from 2019. Interview data is used for RQ1a 5.4.1 and RQ2 5.4.3.

Conversational Agent Probe

We then piloted a conversational agent *technology probe* [88, 222, 37] during the *NewMethod* training workshop (Fig 5.6) January 2020. Probes, as per Hutchinson et al [88], are a design method used to co-design technology with users to learn their needs and desires in real-world settings. Using technology probes also helps

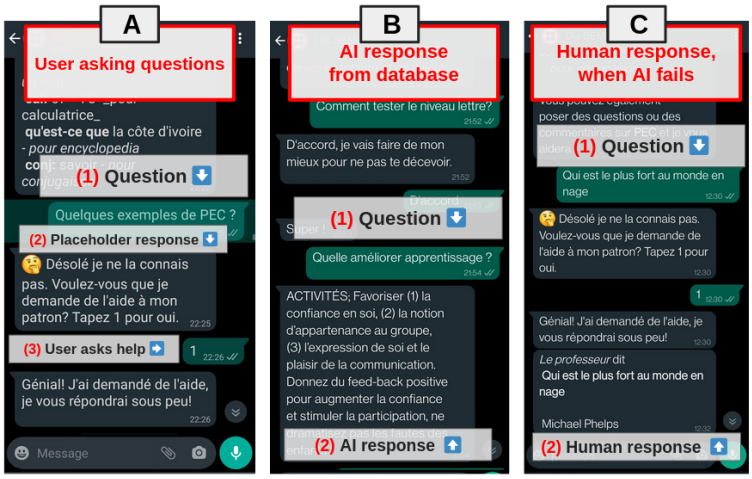

Fig. 5.4.: A representative screenshot of our conversational agent probe [31]: (A) the probe asked the user to type "1" to request human support if the question was outside the database. (B) the probe had some questions related to *NewMethod* and returned responses immediately. (C) When the team answered the question, the agent returned the answer with the user's question.

researchers learn from the usage data to inspire new design directions. The probe was designed using prior work [31], and was intended to support teachers during *NewMethod* implementation. Our conversational agent employed a *humbot* architecture, with a database [31] of frequently asked questions about *NewMethod* which were answered automatically (Fig 5.4 B). When questions fell outside this database, teachers could ask for help (Fig 5.4 A). If teachers requested help with a particular question, it would be flagged in the database, and teachers would receive the answer in a few days (Fig 5.4 C).

We instructed teachers to ask questions to seek help during implementation, i.e., after the training workshop. We also told the teachers that the conversational agent would prioritize answering questions about *NewMethod* and teaching but they were free to ask any questions outside *NewMethod*. Teachers were free to ask questions at any time and were not given any incentive to interact with the conversational agent. Researchers responded to questions referring to the *NewMethod* manual on the teaching method [191] and Google search for complex queries. We found that teachers used the system outside school hours intermittently during the week, i.e., with peak usage on weekends or during evenings on weekdays (refer to our prior work [31] for more information on usage insights). The log data from teachers' questions are used to answer RQ1b 5.4.2.

5.3.4 Data Analysis

We used qualitative analysis to analyze the (1) observations and interviews and the (2) conversational agent log data.

(1) We combined observation notes and interview data from our field into a single data set. We transcribed and translated the interview data into English and formed the low-level themes using thematic analysis [36, 188, 134, 25] to synthesize the themes for our research questions.

We use the *aspirations-avenues-agency* framework [107, 110] to annotate our themes. *Aspirations* translate to longer-term desires [198], *Avenues* are pathways both traditional and non-traditional that users take towards fulfilling their aspirations [162] and *Agency* is the capacity that people build to create these avenues [107]. We also use this framework to situate our findings with our prior work on teacher aspirations [33] and extend this analysis to a pedagogical program.

(2) We transferred the questions from the teachers (110) to a spreadsheet after an initial data cleaning. We translated the questions from French to English and then annotated them into codes, e.g. (Grammar questions, History quotes). These codes were categorized based on the type, i.e., Math; History was classified into "Subject." Finally, these categories were grouped into seven higher-level themes. Table A.1 summarizes our codebook.

5.3.5 Self-disclosure

Our team consists of HCI researchers, economists, and linguists. We are based in North America and Côte d'Ivoire and have conducted research in various developing regions. The first author and the second author are from developing countries, and they formed the protocols and analyzed the data after discussions with the Ivorian team and faculty. We picked conversational agent as a design direction based on our conversations with our partner NGO's team members. Our goal with the subsequent studies is to deploy and evaluate this intervention at scale. The long-term goal of our project is to support teachers with low-cost technology to implement the pedagogical program..

5.4 Findings

We now discuss key themes from our interviews with the teachers around their (1) *NewMethod* and technology, and (2) *NewMethod* and aspirations. We then use these findings to discuss the importance of designing for aspirations.

5.4.1 RQ1a: Technology Opportunities and Challenges

This section describes existing smartphone use by teachers, initial perceptions of new technology, and cultural themes relevant to technology design.

Opportunity: High smartphone adoption, demand-driven internet access

Smartphone access was pervasive among teachers at the study site, and they used it more during the weekends. 33/37 had access to smartphones, and they often had multiple SIM cards from different service providers (MOOV, MTN, and Orange). 21/37 had more than one SIM, 8/37 had all three operators and the rest had one SIM. All had at least one Orange SIM. Teachers switched SIMs for better phone networks, internet, and phone call rates. Teachers mentioned they used their smartphones often to make phone calls and send messages. Teachers said that they used technology after school or during breaks in the context of teaching.

I use it once a day, but it depends. Since I work from Monday to Friday, I use my smartphone on weekends than during school hours on working days. In short, it's more during my days off because I have time and I don't have the pressure of preparing for lessons, correcting a notebook - T3

Teachers said that internet access was a luxury and network access varied by location. Most teachers mentioned that they would connect to the internet only if they needed something, i.e., such as searching for something on the internet or accessing social media. Teachers used internet passes, which temporarily gave them a quota of data to access the internet. Our survey data showed that teachers spent ∼1000 CFA (∼$2) per week on the internet. Internet access was also dependent on the presence of a phone network in their schools and homes. Teachers who lived in urban areas had access at home, but teachers in remote areas connected if they traveled to the city on weekends. Among social media, teachers said Facebook Messenger and WhatsApp are prominent tools for one-on-one interaction due to their convenience and privacy.

Opportunity: Technology usage for professional development and peer support

Teachers used their smartphones for learning new terms on Google and French vocabulary. They used offline applications to look up the meaning of new words in dictionaries and find verb conjugations. According to our survey data, 26/32 teachers used technology to support their classrooms.

I may use the phone at school when I need to know the meaning of a word. I research on the internet to get the answers. It's fast on the internet. Some verbs are difficult to conjugate, so I download applications that allow me to work easily. -T3

Teachers used phone calls to interact with their peers about their professional development. They would call other teachers to discuss a teaching practice or a problem in the classroom. They chose to perform these activities outside class hours. Teachers said they had both requested and helped others through these phone calls. Here, D1 tells us how she calls her friends in the morning.

Classes start at 7:30 a.m. and already at 7:10 a.m., I'm here so I have time to call [a teacher] to ask them: this is such a lesson, or this is such a difficulty that I encounter and how can you help? - D1

Challenge: Smartphone adoption by advisors was limited

Unlike teachers, advisors and trainers did not use smartphones regularly. We observed that trainers did not have smartphones or were still learning to use their devices to access the internet. Master trainer (MT2) had a tablet but accessing the internet drained his battery considerably. Maintaining phone batteries was important because trainers traveled regularly, and they needed their devices to make phone calls to plan their school visits. Advisor (A2) had a smartphone at home, but it did not have internet access as it didn't have a SIM card. He mentioned that his grandkids used the device to play games, and he used the basic phone to make calls. Their prior phone usage patterns, busy travel schedules, and nature of work inhibited them from using the internet on their smartphones.

Opportunity: Initial social media and smartphone usage for the pedagogical program

Teachers also mentioned that they use informal teacher support groups on social media, but social media support for *NewMethod* was still surfacing and limited to directors. Directors mentioned informal social media groups about *NewMethod* where

they could post questions related to the training activity. Our surveys found that 10/38 participants were members of the unofficial Facebook group for *NewMethod* directors, and 5/38 knew about it but were not members. D2 mentioned that they would get support for their problems after class. These informal groups were piloted for selected directors, and *NewMethod* team wanted to extend this support to teachers.

Yes, we created a NewMethod Facebook group, when we had difficulties at the beginning, you could express your problem in the group, and the other members of the group bring solutions, but it is in the evenings that this is happening. There is also a WhatsApp group where we expressed our difficulties. - D2

Lastly, teachers mentioned that multimedia could be helpful in learning activities. We found that directors shared photos and videos of themselves performing the activity on the Facebook group. These posts received better engagement and created a sense of camaraderieD4 echos the utility of multimedia to explain a method to a teacher: *I had images and a video of the session with them (NewMethod team) that I showed him. I lifted [the stick], I present when it goes in the other hand and say 'ONE!'. He looked at the video and saw that it matched what I did.* - D4

Challenge: In-person visits had a socio-cultural benefit that could not be substituted by technology

Advisors, inspectors, and the NGO explained the importance of visits they believed technology could not substitute. A2 explains that meeting teachers and the students provides a human connection that is not into technology. He mentions how he encourages teachers and reinforces their influence on their students.

Advisor: When I visit teachers, I tell them that what they are doing is good. For example, when I observe children who can write, I tell them that they [their teachers] are doing a good job and the reward is not far. We must help teachers, encourage them, and tell them that they are good and can still do better.

Interpreter: can you do it on the phone?

Advisor: We can do it over the phone, but it is not enough, we have to go to the field, and the phone alone is not enough.

Inspector explained the importance of visits which went beyond monitoring but to forming a social connection. The inspector said that teachers feel isolated and need additional social support to help them overcome their struggles. The awareness that their superiors cared enough about their work to visit them improved teachers' motivation to work harder. I1 expresses the benefits of in-person visits:

There is a psychological effect, the fact that the teacher knows that we will come to see him puts him more to work, then on the other side the advantage is that he feels he is not alone. By coaching him, he is also more motivated, and he sees that it is not a solitary adventure.

Despite this perceived value of presence, teachers suggested that they are open to using technology for the pedagogical program if a tool helped them reduce dependence on the advisor. They were mindful of internet access challenges but were willing to spend money if it benefited them. Here T6 expresses his feedback on a storyboard (Fig. A.1,A.2):

We can work with the tech if there is an application available with certain information that can help us simplify and improve our work while allowing us not always to call on the advisor for certain things.

5.4.2 RQ1b: Conversational Agent probe usage

Teachers used the probe for 14 weeks, without incentives. The system was deployed in the context of COVID-19, which was at its peak during weeks 8-12 in the country, and schools were closed during the lockdown. Although schools reopened in 4 weeks there were attendance restrictions due to social distancing, *NewMethod* implementation was halted after the lockdown for the safety of the students.

Teachers asked a total of 110 questions to the probe[2] Our analysis revealed six higher-level themes as shown in Fig 5.5.

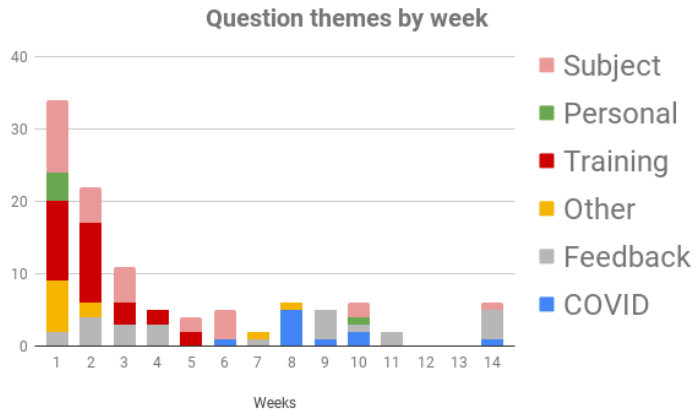

Fig. 5.5.: Summarizes key themes and their distribution over the duration of the study

[2]This number was likely affected by the sudden COVID disruption, beyond challenges of internet access in the context.

Training (24%): high to low level understanding of the program

Pedagogical training questions progressed from questions about goals and motivation, to operational questions, and finally to activity implementation. Initially, teachers asked for general information related to *NewMethod*, e.g., teachers were interested in the objective of the pedagogical program: *What is the purpose of NewMethod?*. Later questions were related to *NewMethod* operations. For instance, teachers were curious about why lower grade students (primary students in the first two grades) were not exposed to the program: *Why is NewMethod not implemented in CP2?*. Finally, we saw activity-level implementation questions during implementation: *How to carry out a NewMethod activity on the image description*, and meta-level questions: *How to arrange activities for better learning?*. These categories and trends hint at different levels of needed support, i.e., general to specific implementation for pedagogical programs.

Subject (27%): short questions about classroom knowledge

We observed that teachers frequently asked questions related to disciplinary subjects from their classroom teaching; in fact, this was the most prominent theme seen consistently across weeks, see Fig 5.5). Teachers asked questions related to Geography, History, Maths, Science, and Grammar, i.e., subjects that they taught at school. These questions were short answer questions, such as geographical facts *What is the smallest state in the world?* or quotes from history *What are the citations of Kant?*. We also saw similar questions asked by more than one teacher, hinting that these questions were related to ongoing classroom topics. Teachers stopped asking questions related to teaching during the lockdown and then restarted asking them once schools reopened.

Non-teaching themes (10%): News, Sports, and COVID-19 information

We also observed that teachers asked miscellaneous questions related to news, sports, and entertainment. Teachers asked about trending news in Côte d'Ivoire and across the world. Some were specifically Ivorian: we received a question when a former Ivorian president was trending - *I want to have the news about the trial of former Ivorian President Laurent Gbagbo*. Others related to world affairs: *I want to know the name of the NBA player who died and the circumstances of his death*, related to Kobe Bryant, a US basketball player's sudden death due to a helicopter crash. Sports questions were about the English premier league or soccer transfers. Teachers mentioned that soccer was their passion in interviews and

played tournaments among teacher groups regularly. Importantly, when the COVID-19 pandemic started and schools locked down, questions were dominated by COVID-19 symptoms, news, and vaccines. While answering these questions, we acknowledged that we were not experts and sent them links from Google.

Social (22%): Conversational messages and greetings

Lastly, we observed that the teachers often greeted the conversational agent informally during interactions. Teachers used smileys: **:) :) :)** or short forms: *Bsr* (short for *Bonsoir* or Good evening) to greet the chatbot. Our formal French language model did not classify these messages as greetings and misinterpreted them as questions. Additionally, teachers wished good thoughts to the conversational agent on occasion about the pandemic or for local festivals (*We pray that this pandemic ends.*; *Happy Easter to all! images.app.goo.gl/cha8w34c21bqe7zka*").

5.4.3 RQ2: How do teachers engage with the implementation of a new pedagogical approach in rural Côte d'Ivoire?

This section explains how teachers engage with the newMethod using a lens of aspirations (Section 2.5). We present how teachers' aspirations [33]., i.e., students' success, improving teaching skills, and career progression interset with the *NewMethod*. Our goal is to use these intersections and translate them into design recommendations in the discussion. *NewMethod* is not the subject of this paper but provides a ripe opportunity to observe these teacher aspirations in practice.

Alignment with teachers' aspirations to improve adoption

NewMethod is centered on students' success. Supporting the attainment of student success was a short-term teacher aspiration that we described in prior work [33]. Teachers mentioned that they could directly observe the benefits of the new pedagogical program through students' increased enthusiasm, participation, and learning. As T10 mentions:

Children love to play and where there is play, children get involved and since the activities are conducted as a game, the children are interested and they play, letters and numbers are like a game, but by playing, they learn.

Teachers explained that they observed a positive impact on their students after only a few weeks of implementation. Teachers also observed improved participation

during program slots which later transferred to regular classroom activities, thus leading teachers to believe that *NewMethod* would play an integral part in students' success. Observing improvements and centering the program on their existing aspirations shaped teacher aspirations towards program adoption. Here, a school director (D1) expresses the program's positive role in students' education in the next few years [3].

My greatest wish is that most children can read and calculate as required by the NewMethod. Because if most children can read, I believe they will do well in composition subjects or the exam. During the various assessments, [..] reading and mathematics are the problems. So if the next three years, if they improve in them, I think the Ivorian school would have won.- D1

Lastly, the program uses teacher role models in the community to inspire the teachers about *NewMethod*. Ministry officials such as advisors, inspectors, and master trainers regularly visited the teachers in their schools to support and encourage program implementation. These officials also perform these activities with the students, which encouraged teachers to implement these activities well. Senior members(master trainers) mentioned regular interaction with the teachers was the program's strength.

Creating new intermediate aspirations through achievable roles

Our prior work found that teachers aspired to progress in their careers to have a broader impact (as advisors or inspectors) on the community but were impeded by the difficult civil service exams required to obtain those roles. The program created new alternative roles that were achievable for teachers to attain simply through program participation. For instance, teachers are called as "facilitators" whose new role is to guide the children towards their learning. All teachers become facilitators after the training. The teacher's role as the facilitator is to build a good relationship with the student, ultimately breaking the authoritative barrier between the teacher and the student. The teachers could play this role by implementing student-centric activities.

The program also offered new leadership positions to create new intermediate aspirations for teachers. Teachers were actively given leadership positions termed as mentors (see Fig 5.6) based on their performance in the program. Mentors were offered a superior social status, additional training, and frequent interactions with superiors. Teachers were chosen as mentors based on their performance and

[3]We asked teachers what change they would like to see in their student's education (i.e., aspirations for their students) inspired by Toyama [198]

Fig. 5.6.: A Director takes the role of a mentor to teach an activity to the teachers during training

participation in the program over the year. As T9 explains, how active program implementation helped his colleagues achieve mentorship positions:

And after the training that took place [..] among all those who took part in these training, I saw some who became mentors because they took seriously what they did. In life, when you do something, you have to take it seriously. Even if we put everything at our disposal, if we work negligently, we will not evolve. -T9

Allowing teacher's collective agency to scale and sustain the program

NewMethod creates pathways that allow teachers to realize their potential, whose collective work benefits teachers themselves and the program. As described above, teachers' career progression was impeded by difficult exams. The program's mentor role created an alternative pathway for teachers to exercise their agency for intermediate career progression. The mentor role required training and supporting fellow teachers providing mutual benefit to the program and the teacher. Here D2 explains how his aspirations to improve in his career led him to utilize these pathways to rise in the program's ranks.

In everything, we dream of climbing the ladder; to get there, we must do our job better [...] I want to become an inspector or educational advisor [...] This is why when there is a new pedagogy. I appropriate it with all my heart and one hundred percent. I go through all means to master it to be able to dispense it well. Here we are four who have been listed as mentors not because the others are bad, but you have to know how to be noticed positively. - D2

Teachers rising to mentor positions also paved the way for scaling and sustaining the program. The mentor roles were structured to fill in for the limited pedagogical

advisors when the program scaled to more schools. Mentors also acted as the first support system to their fellow school teachers and teachers in the vicinity, reducing their dependency on the advisor, who would usually be remote. Ministry officials also recognized teachers' potential and welcomed their support. Here, Advisor(A2) explains that he will retire soon but believes teachers are the future.

Logically, I am going to retire in July 2021 so I have 1 year left. [..] but they (teachers) are still young and we need someone to do the training if the NewMethod is to be popularized on a national scale. There are more than 17,000 schools in the Ivory Coast, if all the schools have to implement NewMethod then we need people to train them because there will not be many national trainers(superiors) to do all this work. -A2

5.5 Discussion

This section connects our findings from the technology probe and teacher aspirations toward designing sustainable systems. Our probe's goal was to learn the scope for remote mentoring for teacher training in *NewMethod* (see storyboard Figs. A.1 and A.2). Teachers were able to engage with a new technology over many weeks, demonstrating the usability of the tool in a new context. Our qualitative analysis of teacher questions identifies themes in teaching, teacher training, and non-teaching scenarios expanding the scope of support such a tool could provide in remote mentoring. In the first section, we use findings from RQ1a (Section 5.4.1) and RQ1b (Section 5.4.2) to demonstrate sustainability challenges by situating technology purely on teachers' needs and then, suggest ways to overcome these limitations using data from RQ2 (Section 5.4.3) and theoretical connections to aspirations.

Critiquing designs on needs-based approach

Our data from RQ1a (Section 5.4.1) and RQ1b (Section 5.4.2) discovered that teacher needs could not be addressed solely digitally by advisors, as there was a cultural significance to in-person visits. We expected a tool like this to amplify the relationship between stakeholders digitally, i.e., teachers could seek help from their supervisors (advisors) using a tool like a conversational agent in the future. However, our data suggest that such a tool is not practical for this scenario because advisors could not transfer all their work digitally. Firstly, we expected the advisors to answer teachers' questions, but we learned that the advisors did not have smartphones or were already overloaded to take on this additional responsibility. Instead, advisors and trainers continued to spend their time on in-person visits, which they

believed played a significant role in supporting the teachers. Secondly, all stakeholders mentioned the cultural significance of in-person visits, which technology could not substitute. Advisors said that meeting the teachers in person positively affected teachers as they saw a respected person take an active role in their lives. Approaching the problem with a needs-based approach creates an external imposition [198, 147] which fails to allow for practical use cases. Needs, as Toyama mentioned [198] are centered on negative feelings, thus leading to designs that are externally imposed or aim to support fleeting problems.

We also learned that teacher needs were transient [198, 147]. We noticed that question topics gradually changed over time; some went outside the scope of teaching or teacher training. Teachers asked questions about COVID-19 symptoms or very context-specific, e.g., (*How to start cattle business?*). This question trend confirms that teacher needs are transient [198, 147]. Hence it is hard for future designs to support such scenarios in the long term.

5.5.1 Towards Designing for Teacher Aspirations

We now describe alternative approaches to address the limitations of needs identified in the previous section using data from RQ2 (Section 5.4.3) and theoretical connections to aspirations. For each subsection, we first explain our finding, then provide an example in the context of our conversational agent scenario and then connect it to the broader literature.

Designing for Teacher Agency

Our finding on utilizing collective teacher agency can be translated into technology design through improved structures that enhance their capacity to engage in peer support in rural communities. While in-person support from experts was seen as vital, our data also supports peer-based learning; for instance, D1 describes how she comes to school early to seek help from peers for her lessons *I'm here (early), so I have time to call someone (teacher) to ask them: this is such a lesson, or this is such a difficulty that I encounter and how can you help?*. However, rural teachers' existing collegial networks for relevant professional development support was limited, as regions tend to be small. Technology can expand a rural teacher's limited collegial network by providing connections outside their social circle to teachers in different regions with different perspectives on professional development support. Beyond simply greater access to peers, conversational agents could have a role in better facilitating these support conversations. Prior work by Toxtli et al. [197] allowed expert users to provide asynchronous answers to novices' questions through

a conversational agent. We can extend Toxteli et al.'s [197] designs to focus on teacher peer support (instead of limited experts) by allowing teachers to answer each others' questions within a conversational agent. For instance, agent designs could facilitate appropriate conversations by making connections to the most relevant peers based on expertise, location, or usage. Drawing on A2's assertion that teachers themselves are needed to scale and sustain the program, a conversational agent design could also learn from teachers' answers to their peers and answer future similar questions, reducing reliance on limited experts in low-infrastructure contexts while drawing on teachers' own expertise [74, 197]. Therefore, there are opportunities to extend peer support to rural teachers in chat-based scenarios that rely on collective teacher support to enhance in-person support provided by advisors.

Shaping Aspirations for Technology Adoption

Our findings for role model champions and aligning interventions towards existing aspirations could be translated towards improved technology adoption. In our context, ministry officials championing the program and centering the program's messaging on students' success led to organic program adoption among the teachers. For our chat-based scenario, role models could be integrated into intervention deployment as community champions [130] i.e., inspectors and advisors could advocate and use the technology during school visits to explain the intervention's valuable role towards student success. ICTD literature has emphasized the importance of role models and mentors [110, 198, 100]. Prior literature in economics has demonstrated how villages with female leaders showed improvements in parents' investments in their daughter's education [21]. In these villages, parents' and children's educational aspirations increased when they observed these female leaders taking a more ambitious role in society. In the ICTD literature, Pérez et al. used role models in *Tika Vani* to choose characters of marginal groups (lower caste) as protagonists in their designs to inspire inclusive m-health technology adoption [150]. Such interaction techniques allow for positive social proof [207] by observing the success of people similar to them, therefore helping them become more ambitious about their aspirations. Designers could use this construct to shape aspirations by using role models in their technology designs.

Creating New Aspirations for Behaviour Change

We learned from our findings that interventions could create new aspirations to allow positive behavior change. Our data reveals that *NewMethod* created leadership

roles (mentors) aligned with teachers' aspirations to increase their impact on their community through career progression [33]. These roles acted as an achievable intermediate aspiration towards impacting the community allowing for a positive behavior change, i.e., convincing teachers to implement the program. For our chat-based scenario, digital and non-digital leadership roles could be designed for teachers to support community members. For digital roles, teachers could be given a superior status based on their technology usage, such as community moderation roles given to active users in *Sangeeth Swara* [206]. Alternatively, voluntary positions (technology mentors) could be created outside technology to allow mentoring on technology-related issues. In ICTD literature, creating aspirations can be linked with Kumar's perspective [107] on how aspirations can be modeled as sequential milestones, i.e., achieving one aspiration improves agency to achieve future aspirations. Therefore creating the apt intermediate milestone can change behavior by utilizing user aspiration. Prior work has demonstrated this at scale: *no toilet no bride* campaign [187] used the aspirations of youth to find eligible brides to convince them to build a toilet in their homes. In rural India, the campaign improved ownership of latrines by 21% in homes with the youth of marriageable age. These examples show that creating new aspirations that align with broader users' aspirations can change behavior. Designers can use these opportunities to model new aspirations inside or outside technology to help promote behavior change.

5.5.2 Reflections on applying Aspirations

Providing agency, creating and shaping aspirations align with Appadurai's [10] suggestion to raise the user's capacity to aspire. Users in low resource contexts often lag in their aspirations, are unable to harness capabilities, or lack the relevant information to convert their desires from *wishful thinking to thoughtful wishing*. Our findings demonstrate a positive role that can be played in supporting users in their aspirations by using interventions to shape existing and create new aspirations. We are excited for ICTD researchers, practitioners, and theorists to extend our work.

Our research taught us that it is essential to convince partners on *Why aspirations?*. During our research, we discovered that our NGO partner was more interested in their organizational goals to deliver improved educational outcomes than prioritizing teachers' long term career aspirations. The NGO deeply cared about teachers and was doing its best to support them, but teachers career aspirations fell outside their scope. We believe more work is needed to demonstrate the impact of aligning long term aspirations to practitioners and policymakers outside academia.

Our research also induces the question: *Which aspirations? Who prioritizes them?*. We chose career aspirations to align with our expertise and funder goals. However,

teachers also had personal aspirations related to their families' well-being or financial outcomes, which we could not support through this project. Kumar et al. [110] highlight this question in their research when they mention the role of the researcher in uncovering aspirations in their work.

5.6 Conclusion

Most technology projects in developing contexts, even if well-intended, fail to deliver long-term impact beyond academic research. Therefore ICTD scholars have suggested an aspirations-based approach to design sustainable systems. However, recent research found that teachers' professional aspirations can conflict with their current professional responsibilities, increasing the complexity of design technology in such circumstances. We first deployed a chatbot probe over a 5-month long study to support teacher training to understand such complex design spaces. Although the tool successfully addressed teacher training needs, our data show that needs-based approaches are not sustainable as needs varied over time, amplified existing inequalities, and took agency away from the teacher. Secondly, we uncover design ideas for teacher aspirations through a qualitative study with 30 teachers in rural Côte d'Ivoire during a new teacher training program. We show that the teacher training program relies on teachers aspirations, shapes their future aspirations, and relies on teacher agency leading to a sustainable ecosystem to achieve long-term outcomes. We use our data to recommend design ideas to operationalize aspirations by creating communities and designing for teacher agency. We reflect on the importance of communicating *why aspirations* to practitioners, which aspirations to prioritize, and how to address these aspirations. Our contributions present initial design ideas towards developing sustainable technology in low infrastructure settings for teacher aspirations.

Study 3: Pilot

6

6.1 Overview

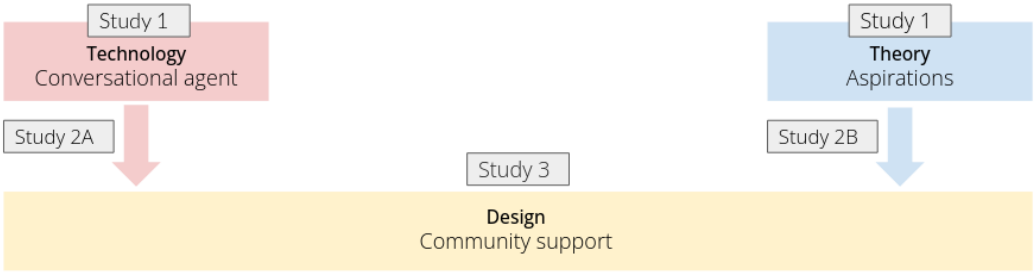

Fig. 6.1.: The goal for study 3 was to pilot my initial set of designs about community support. My work from study 2A led me to designs that allowed for community support in a conversational agent

Study 1 described teachers' smartphone usage and their aspirations in rural Côte d'Ivoire. I learned that teachers had challenges in professional development but used smartphones to support their classroom teaching. Therefore, in study 2A, I deployed a conversational agent probe and teachers' engagement with a pedagogical program. I discovered initial evidence that a conversational agent is feasible to support teachers through remote mentoring.

I extended my work in study 2B to uncover design ideas for teacher aspirations through a qualitative study with 30 teachers in rural Côte d'Ivoire during a new pedagogical program. I showed that the program is centered on teachers' aspirations, shapes their future aspirations, and relies on teacher agency leading to a sustainable ecosystem to achieve long-term outcomes. Using my findings, I proposed creating community support designs that allow for teacher agency.

Therefore for study 3(refer Fig 6.1), I expect to pilot an initial design with community support designs for a conversational agent. To explore this new design space, we deployed a conversational agent on Messenger to 120 teachers for four weeks to support a new pedagogical program in rural Côte d'Ivoire.

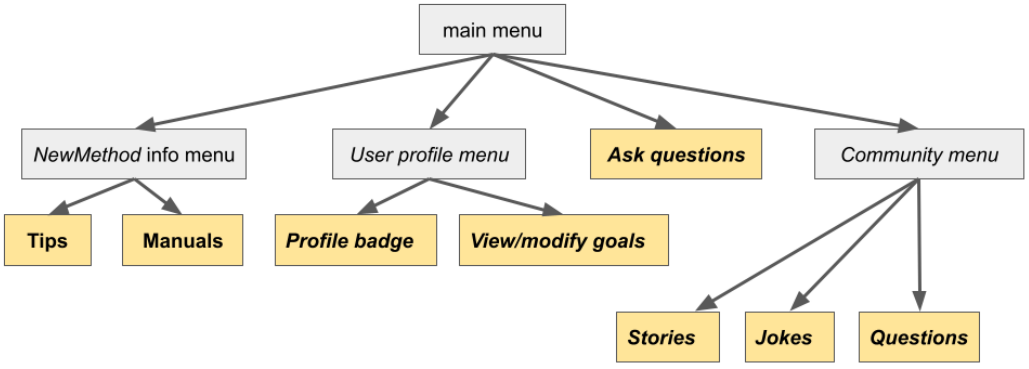

Fig. 6.2.: This figure shows a flowchart explaining the various features of the system. A gray box represents a menu and a yellow box represents a feature

6.2 Design Iteration

We extend prior [31] work through the following design iterations. The flow chart depicts the various features of the conversational agent and the menu hierarchy for accessing them.

- `USSD Menus`: We redesigned the conversational agent using USSD menus(menus with numeric options), which are interactions familiar to the context. Users would be presented with a menu with numerical options which lead to the subsequent menus or features.
- `Main Menu`: The main menu was the default content shown to the users. Users could always access it by typing "0".
- `NewMethod Information`: This menu gave users (a) Tips: curated short content about the *NewMethod* program from the manual, (b) Manuals: *NewMethod* manuals gave users access to documents related to *NewMethod* for French and Math.
- `User Profile Menu`: This menu gave users (a) Goals: which allowed users to view and modify previously selected goals. These were supposed to support the teachers reflect on their work for the week (b) Profile badge: users could view a visual of their profile picture and demographic information.

- `Questions`: Users could directly interact with the conversational agent by asking questions. However, we added a menu option to guide users who may need additional scaffolding. We still had the human-AI hybrid interaction with an improved database of questions.
- `Community Menu`: We also had the community feature where users could (a) share and read experiences about *NewMethod*, (b) share and read jokes, or (c) could answer curated questions. These were experimental with sample content curated by the researchers.
- `Introductory tutorial`: There were introductory survey questions with example interactions to onboard the teachers into the system. These questions were intended as conversational agent training sessions during the teacher training.

6.3 Research Questions

RQ1: How do teachers engage with a conversational agent with a community support feature?

RQ2: What are the usability challenges for teachers using the conversational agent's features?

6.4 Study Design

This study is part of an ongoing research project to improve children's education in rural Côte d'Ivoire through poverty reduction and improved education for rural cocoa farming communities. An interdisciplinary team from Ivorian and North American universities conducted this study in partnership with the Ivorian Ministry of Education. We received approvals from all our institutional boards and the Ivorian government to conduct the study.

6.4.1 Site Description

We conducted the study in a southwest region in Côte d'Ivoire. French is the official language of Côte d'Ivoire, but there are nearly 70 local languages [181]. This site primarily has an agricultural economy based on cocoa and coffee, which have been residents' primary source of income for decades [102].

Tab. 6.1.: Table summarizing our data sources collected by the team

Observations	
Participants	∼120
Duration	6 days (9AM - 5PM)
Stakeholders	Teachers ∼100, Directors: 20, Advisors 2
Surveys	
Participants	50
Gender	Female: 12 Male: 38
Stakeholders (2)	Teacher: 27, Directors: 23
conversational agent deployment	
Participants	100
Duration	6 weeks
Interviews (after 2 weeks)	
Participants	25
Gender	Female: 5 Male: 20
Stakeholders (4)	System users (2): Teachers: 15, Directors: 5 System non users (2): Teachers (3), Directors (2)
Schools (7)	Users: 5, Non users 2
NewMethod observations	10 hrs
Subjects	CP1-CM2 (3rd-6th grade)
Think Aloud Surveys	
Participants	20
Gender	Female: 4 Male: 16
Stakeholders (2)	Teacher: 13, Directors: 7

The study site *Méagui* is a rural farming town in the Soubré region. It has a few urban schools inside the city, while the remaining rural schools are distributed in communities away from the city. Communities situated away from the city have lower infrastructure: i.e., they lack adequate water, electricity, and telephone signal. Remote communities have poor road conditions, which further impedes travel and increases their isolation. Students in these rural communities have low literacy rates, influenced by the rural context and low infrastructure [121, 120].

Field Observations

The research team observed and participated in the *NewMethod* training activities throughout the week. We recorded our field notes and discussions in our research journal and used these lessons to refine our questions for our surveys and interviews. These observations helped us get a glimpse of the situated struggles (sitting on the floor for long-duration, heat) and bonding experiences (singing, dancing)

during this challenging week. Relevant media from these observations were shared on the Facebook page and the conversational agent to contextualize the intervention.

Surveys

Fifty users were surveyed during the teacher training . Most survey responses were recorded during breaks or after the teacher training sessions. The surveys were conducted using a form on ODK to account for network issues. The surveys about teachers technology and social media usage, demographic information and *NewMethod* questions. The surveys typically took 20 mins for the teachers.

conversational agent pilot deployment

We then piloted a conversational agent technology during the *NewMethod* training workshop (Fig 5.6) May 2021. The system was designed using prior work [31], and was intended to support teachers during *NewMethod* implementation. The conversational agent was a *humbot* architecture i.e. the questions were answered by the system and the moderator. When questions fell outside this database, teachers would receive the answer in a few days.

After the training sessions, we instructed teachers to ask questions about *NewMethod* to seek help during implementation i.e. after the training workshop. Teachers were not given any incentive to interact with the conversational agent. Teachers were also provided a Facebook page connected to the conversational agent. Researchers responded to questions referring to the *NewMethod* manual on the teaching method [191]. We collected log data from the conversational agent and the Facebook page for six weeks. However, the school year concluded in three weeks.

Think Aloud Surveys

After two weeks of deployment, we revisited the teachers in their community and conducted think-aloud sessions [115]. The think-aloud sessions involved a series of questions where teachers had to perform various activities on the conversational agent. For e.g. send a "hello" message to the conversational agent, like a post on the Facebook page, etc. Participants were given 3 attempts to perform the activity after which the interviewer recorded the attempt on a survey. We also recorded the teacher's screens as they performed the activity to get a contextual understanding

of teachers' usage behaviors. The think aloud surveys typically took 20 mins for the teachers.

6.4.2 Data Analysis

We used mixed-method analysis to analyze the (1) observations and interviews and the (2) conversational agent log data (3) quantitative analysis of teachers usage.

(1) We combined observation notes, think aloud notes, Facebook page comments, and interview data into a single data set. We transcribed and translated the interview data into English and formed the low-level themes using thematic analysis [36, 188, 134, 25] to synthesize preliminary themes for our research questions.

(2) We analyzed the conversational agent log data based on teachers interaction with the menus and the different features. We transferred the questions and stories from the teachers to a spreadsheet after an initial data cleaning to understand some preliminary themes.

6.4.3 Self-disclosure

Our team consists of HCI researchers, economists, and linguists. We are based in North America and Côte d'Ivoire and have conducted research in various developing regions. The first author and the second author are from developing countries, and they formed the protocols and analyzed the data after discussions with the Ivorian team and faculty. The long term goal of our project is to support teachers with a low cost technology to implement the pedagogical program.

6.5 Preliminary Findings

6.5.1 RQ1: conversational agent engagement

Training and icebreakers: Teachers engaged the most on the day of the training session when the advisor supported the research team. We observed the highest engagement on Day 3 (see Fig 6.3) when the research team convinced the advisor in a region to help me. After being convinced, the advisor paused the *NewMethod* training session for a while to enable the *DIA* research team to train the teachers on the conversational agent. Our original idea was to train teachers during the break sessions (Day 1 and Day2), which worked less efficiently. Icebreaker sessions were

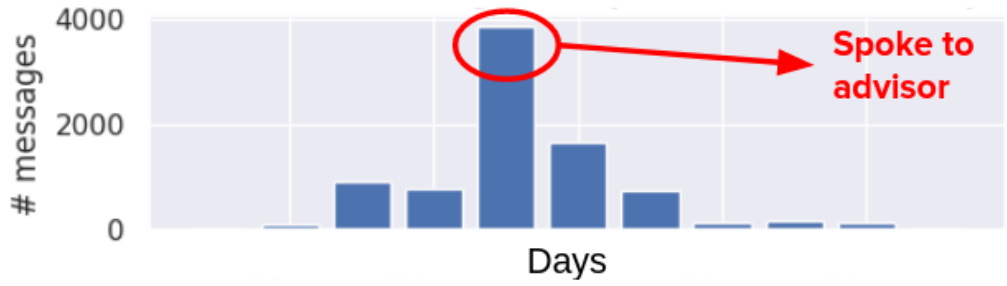

Fig. 6.3.: Total daily messages over the first ten days. Teachers engaged the conversational agent the most on Day3, i.e. when the advisor supported research team during teacher training.

typical during *NewMethod* training; teachers would be tired during the long training sessions. Hence the trainers incorporated; dancing and singing between sessions. Trainers improved social bonding in the *NewMethod* workshops by encouraging teachers to learn and support their neighbors (*voisin*).

Data constraints: We noticed that the teachers' usage significantly tapered off after the training week. Teachers mentioned in our interviews that they had difficulty accessing the conversational agent as data was expensive or the network was unavailable. They requested more offline content that would support them during limited data constraints. As T9 explains with an example: *The agent allows me to download (the manual) on my phone, and I take my time to read the textbook in French and was able to adapt it better(for NewMethod), and this is what I liked. - t9*

Participatory content: We also piloted the participatory content features for stories, jokes, and questions. I found that teachers shared experiences with the *NewMethod* program. A representative story: *Since I started studying NewMethod with the students, they have become very happy and participate a lot it allows many students to know how to read and write*. Teachers also shared concerns. For example, sitting on the floor, which was part of the *NewMethod* program but new to teachers, here a teacher expresses this through a humorous example: *One day during an activity NewMethod my students told me to stand up to talk to them*. Inspired by icebreakers (in Study 2), we also allowed teachers to share jokes which generated content for *NewMethod* and general topics. Although *NewMethod* jokes were fewer, teachers shared a few related to the training activities, e.g., *It took the NewMethod to see that teachers do not know how to dance.*.

***NewMethod* Questions**: Like study 2, Teachers also asked questions to the conversational agent. We had 300 questions, and most were related to *NewMethod*. We found that the categories were very similar to Study 2, i.e.informational, operational, and activity. We had (a) informational questions about the program. *What is the objective of the NewMethod?*, *The five principles of NewMethod*. We also had

(b) operational questions about the different processes: *What is the role of the local mentor?*, *What are the stages of the Aser test*. Lastly, we had specific (c) activity level questions: *I would like more explanations on Step 5- Activities in-group understanding*. We also observed that, unlike Study 2, teachers asked a few questions outside of *NewMethod What does Dia mean ???*.

Experimental question answering: We piloted an experimental feature that allowed teachers to answer questions. We curated a few informational and operational questions, to which teachers were able to provide answers. For example, the question: Why is the program not taught at the CP level, received: *The NewMethod is not at CP because it is essential, because the objective of the NewMethod is to give an excellent base to the other classes*. We also tested multimedia questions asking them to name an activity, and we got ten correct responses.

We also observed that teachers accessed the community menu from our log data. 28% of the aggregate interactions were the community menu, behind 32% of the default welcome menu and ahead of the subsequent 17% tips menu. Teachers also mentioned that they liked the stories and jokes from the conversational agent. In our interviews, teachers expressed that they liked the stories from their colleagues to be useful: *I learned some things, for example, the anecdotes, the stories that colleagues shared on the conversational agent- D1*.

6.5.2 RQ2: conversational agent usability

Most teachers, i.e., 16/20 (80%), we're able to navigate the system after two weeks, demonstrating its ease of use. Additionally, free basics on the MTN network helped teachers access Messenger and Facebook without incurring data charges. 14/20 teachers (70%) used more than half the features; I categorized them as experts and explained their usage compared to the remaining (novice) users.

Experts(70% top) were immersed in the conversational agent, i.e., had a nuanced usage. For example, they used the "buttons" instead of typing the numbers, which improved their navigation speed. They also remembered that "0" is the "home menu," which helped them get unstuck during complex navigation. Experts would also quickly zoom into the relevant section in the menu to focus on the relevant information rather than reading the entire text. Additionally, they would confidently navigate the current menu for subsequent tasks instead of restarting their search after every task.

Novices (remaining 30%) often got overwhelmed with the task or the information in the menus. Novices were often hesitant to attempt the task; the research assistant would encourage them at times to attempt instead of giving up without trying.

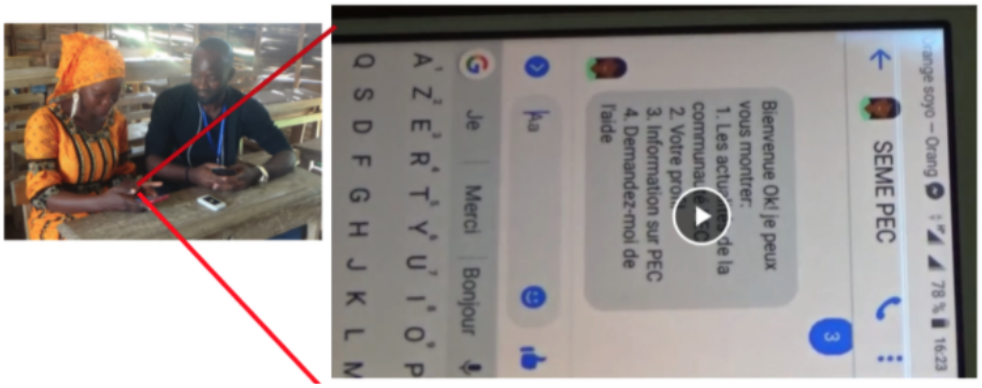

Fig. 6.4.: Think aloud session with a teacher, conducted 2 weeks after training. The teachers were asked to access a feature while the interviewer recorded their attempt on a survey. Teachers were given 3 attempts per feature and the entire session was recorded on video.

1. Bonjour	2. Survey	3. Goals	4. Browse	5. Tips	6. Manual	7. Ask question	8a. Access story	8a. Access joke	8.b Add story	8.b Answer question	
1	1	0	0	0	0	0	0	0	0	0	18.1
1	1	0	1	0	1	1	1	1	1	1	81.8
1	1	0	1	0	1	1	0	1	1	1	72.7
1	1	0	1	0	0	1	0	0	0	0	36.3
1	1	1	1	1	0	1	0	0	0	0	54.5
1	1	0	1	1	1	1	1	1	1	0	81.8
1	1	0	1	1	1	1	1	1	1	0	81.8
1	1	1	1	1	1	1	1	1	1	1	100
1	1	0	1	1	1	1	0	1	1	0	72.7
1	1	0	1	1	1	1	1	1	1	1	90.9
1	1	0	1	1	1	0	1	1	1	1	81.8
1	1	1	1	1	1	0	1	1	0	1	81.8
1	1	0	0	1	1	1	1	1	1	1	81.8
1	1	1	1	1	1	1	1	1	1	1	100
1	1	0	0	1	0	0	1	0	1	0	45.4
1	1	0	0	1	1	0	0	0	0	0	36.3
1	1	1	1	1	1	1	1	1	1	1	100
1	1	1	1	0	1	1	1	1	1	1	90.9
1	1	0	1	1	1	1	1	1	1	1	90.9
1	1	1	1	1	1	1	1	1	1	1	100
100	100	35	80	75	80	75	70	75	75	60	

Fig. 6.5.: Success rate of the think aloud by feature and teacher. Each row represents a teacher and each column represents a feature. A green box indicates success and a red box indicates failure. The columns at the end indicate aggregate success percentage for the user. The last row indicates aggregate success percent for the feature

Novices would also get overwhelmed by the amount of text in a menu and slowly read the menus. They would often derive wrong mental models of the menu system (e.g., referencing incorrect menus or typing the unintended menu option). Typing wrong inputs often led them to wrong menus and lost focus; often, the interviewer had to remind them of their task. Additionally, novices didn't remember that 0 was home, thus finding it difficult to complete or restart a task.

In general, teachers typed very slowly. We observed that all teachers typed very slowly, and often each input took an average of 2-3 mins to type 30 words of text. Teachers did not use auto-suggest. Instead, they typed every letter slowing their speed. We also noticed that some devices had physical limitations (scratches, cracks) or worked very slowly, making it hard to type and use the applications.

6.6 Discussion

Our data gave us initial evidence to confirm that these features for participatory content could provide community support. Community members could share information for *NewMethod*, jokes, and even answer questions. Our log data showed that the community was the most popular feature. Additionally, our observations taught that most teachers could use the conversational agent well enough and enrage with the various components with basic training. Technology training worked well when we had support from the mentor. Lastly, we learned that teachers expected more offline interactions as they experienced difficulty accessing the conversational agent due to network or data constraints. The questions from teachers helped us augment our database for future studies.

These ideas helped us refine our thinking on community support designs, improve training content and design more offline interactions to accommodate access. We acknowledge that teachers used the system for a brief period, i.e., four weeks, and these weeks involved an above-average workload as teachers were concluding the school year. Additionally, teachers received the *NewMethod* training as an introduction for the subsequent school year. The short program implementation narrowed opportunities for the conversational agent to support teachers. Therefore, it helped us pilot features, but we expect to discover opportunities for impact from the conversational agent for future work.

Study 4: Evaluation

7

7.1 Overview

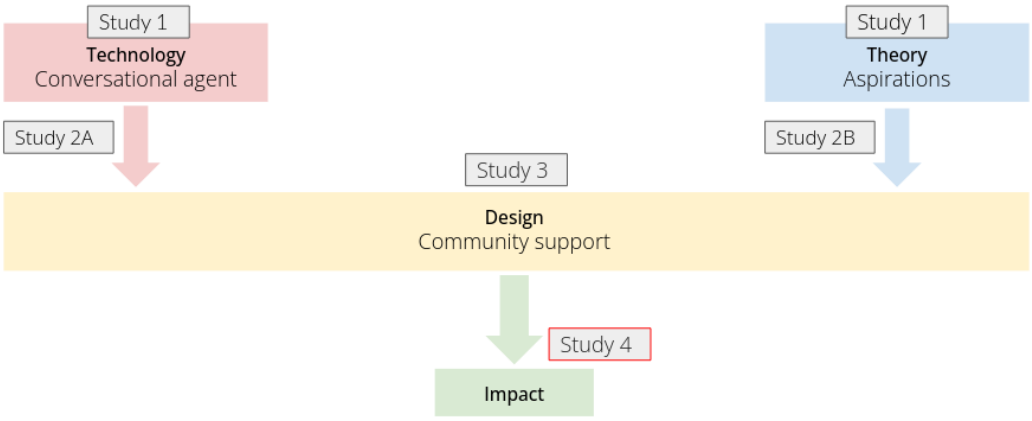

Fig. 7.1.: My goal for Study 4 is to measure the impact of community support designs that I piloted in study 3.

My findings from study 1 helped me understand teachers' smartphone use, thus designing a conversational agent that could address teachers' professional development struggles. In study 2A, I discovered initial evidence that a conversational agent is feasible to support teachers through remote mentoring. However, it was still unclear after study 1 how to implement teacher aspirations in technology designs such as a conversational agent. In study 2B, to explore the use of conversational agent technology in this design space, we conducted a qualitative study with 20 teachers and ministry officials in rural Côte d'Ivoire to understand opportunities and challenges in technology use for these stakeholders. We used our data from teachers and proposed designing for teacher aspirations through community support, i.e., collective peer support from teachers, allowing sustainable designs to overcome shortcomings of working purely on teacher needs.

In study 3, I piloted initial designs allowing community support through participatory content in a conversational agent. Our system allowed teachers to contribute and consume stories about the program, peer-based question support, and informal jokes. Our preliminary analysis from log data and interviews revealed that teachers valued these community features.

For study 4 (refer Fig 7.1), I evaluate the impact of community support designs at scale. I categorize impact as teacher motivation, training knowledge, and technology adoption (refer Fig 7.4). I hypothesize that community support features will have a better impact than individual support by allowing early adopters to participate easily. To investigate this hypothesis, I deployed a conversational agent in two regions with the community and individual support as conditions.

7.2 Design Iteration

Based on our findings from Study 3, we iterated on the system, which led to the following design changes. The flowchart depicts the updated system (Refer to Section 6.2 for prior system context) with the highlighted modifications.

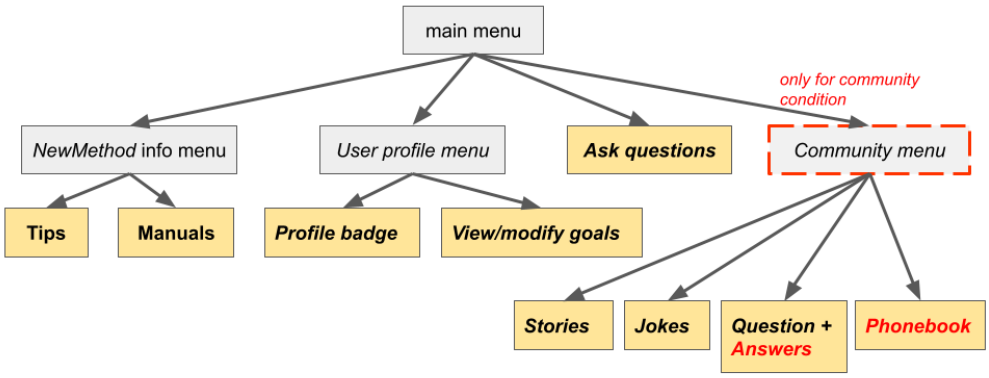

Fig. 7.2.: Flowchart of system features and design changes

- **Introductory tutorial**: We expanded the introductory survey and messages to guide the users through the various features of the conversational agent. The new tutorial gives teachers a prompt(👉) to type the appropriate menu option. We followed Kraut's suggestion to onboard users into a new social networking system. The research team guided the teachers using the features and the training manual (on paper), which explained each feature in detail.

- **Simpler menu structure**: Our think-aloud observation from study 3 showed that teachers found it hard to remember menu information. Therefore, we

used concise text (*NewMethod tips and manual* instead of *NewMethod information*, which was ambiguous. We found that teachers found it hard to read the entire text. Therefore we used emojis in the first letter (👨‍👩‍👧 Community) to help teachers quickly grasp the menu content.

- **Consistent home menu**: In our observations from study 3, we found that teachers occasionally lost track of their navigation while browsing the menus. Although we explained that 0 was home in the tutorial, teachers couldn't recollect it. Therefore, we tweaked the Facebook messenger settings to display a button:*Tap 0 for home* whenever teachers opened the conversational agent. Tapping the button would open the home menu, thus allowing teachers to continue navigating the conversational agent.

- **Support for two conditions**: To answer our research question 7.3, we created two versions of the conversational agent. Teachers in Region 1 received menus that reflected individual support, while teachers in Region 2 received menus with community support features. Connections to the community menus were omitted in the individual support (Fig 7.2).

7.2.1 Community Support Design Iteration

- **Improved Community Menu**: I also had the community features with participatory content. I found in Study 3 that teachers shared experiences about the *NewMethod* program and classroom experiences. Teachers expressed that they valued participatory content shared by their peers in our interview data. Thus, providing initial evidence to confirm that these features for participatory content could provide community support. Therefore, we updated our features with (a) stories: for teachers to share and read experiences about *NewMethod*, (b) jokes: to share and read humorous content, or (c) question+answers: where teachers could answer questions from other teachers. The community content displayed the latest information shared by community members as a news feed. e.g., if the teacher opened a story menu, they would see the newest story from another teacher. We chose this design so teachers would have an example before inputting content. The community content served a personalized news feed, i.e., upon further navigation, each teacher would only see content they hadn't seen before, thus creating a dynamic experience for the teacher.

- **Phone book**: The conversational agent in the community condition provided contact details of fellow teachers through the phonebook feature. The storyboard explains the phone book(Fig 7.3) feature. We based this design on our

data from Study 2, where teachers mentioned calling each other to support. We expect the phone book could provide another channel to connect with community members through offline interactions. The phone book would provide a personalized dynamic list of teachers every week. Before showing the first number, we gave teachers a tip to encourage their colleagues over the phone. The list consisted of one active user, one moderately active user, and one inactive user. The teachers would get one phone number at a time and would have the option to provide feedback after a number. Additionally, we expected the phone book to serve as a channel for communication in low-data settings. Teachers in study 3 asked for more offline content because of limited data constraints. We designed the phone book to facilitate phone conversations when teachers were constrained on data as the phone number would be on the chatlog even without the internet. We had a section in the training manual to explain this feature. We used neighbor (*voisin*), a vocabulary used in an icebreaker activity during *NewMethod* training sessions.

- **Question Answering**: In study 3, the researchers curated the initial content for community support as they were experimental. We found that some teachers provided reasonable answers to curated questions; therefore, we added an experimental feature to allow teachers to answer other teachers' questions. After approval from the NGO worker, we displayed the "questions" in the "questions" section of the community menu in the conversational agent.

- **Content Moderation**: An NGO worker moderated all community content through a dashboard. The dashboard allowed the NGO worker to answer teachers' questions and observe answers shared by the conversational agent. If the NGO worker responded to the question, the message would go to that conversational agent, and an SMS would be sent to the user, again to account for low data settings as requested by the users in study 3. The dashboard also had a page for editing and approving community-generated stories, jokes, and answers. The NGO worker requested an editing feature as teachers often made mistakes when entering long stories through their phones.

- **Multimedia support**: Lastly, to improve interactivity, we allowed teachers to share multimedia interactions (video, voice, and pictures) through the conversational agent. We expressed using emojis that the system was open to image, voice, or text-related input. We observed that some teachers in study 3 organically shared the photos with the Facebook page and the conversational agent, thus inspiring us to foster more multimedia interactions. Our partners also informed us that directors in internal WhatsApp groups would share photos of *NewMethod* activity.

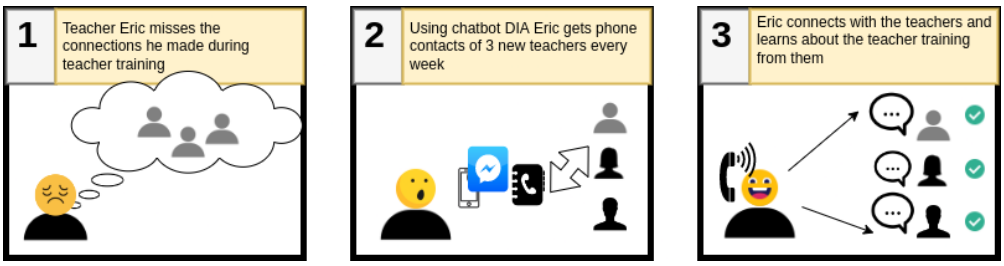

Fig. 7.3.: Storyboard representing the phone book feature. The phone book would provide a personalized dynamic list of teachers every week. We based this design on our data from Study 2, where teachers mentioned calling each other for support.

7.3 Thesis Research Question

The central question of my dissertation is:

How does a conversational agent that supports a virtual community of practice (vCOP) impact teachers in low infrastructure settings?

I categorize impact as (a) Teachers' motivation to implement the program, (b) Teachers' knowledge (and skills) about the training, and (c) Technology adoption by the teachers. An ideal intervention's adoption would influence (a) and (b) through the various designs, leading to impact.

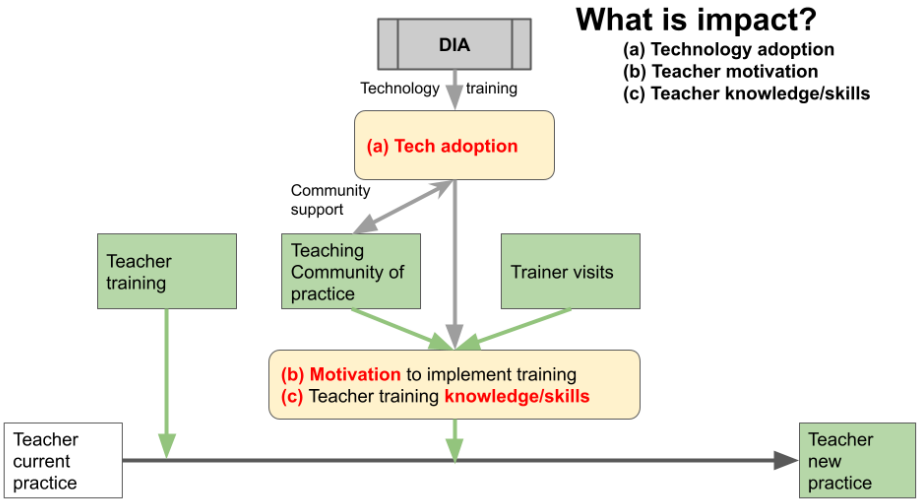

Fig. 7.4.: Theory of change explaining impact. We categorize impact as (a) Technology adoption, (b) Teachers' motivation to implement the program, and (c) Teachers' knowledge/skills about the training. We hypothesize that active users will utilize the community features, thus leading to more motivation and knowledge.

The diagram (Fig 7.4) explains how current teacher practice(left) is influenced by teacher training to lead to new teacher practice (right). Teachers are first trained during a week-long teacher training, giving them the foundational knowledge and motivation to implement the training. After training, teachers are influenced by the teaching community and trainer visits. The teaching community consists of teachers in the same school and teachers in the vicinity. Therefore, teachers interact with these community members on official and social interactions throughout the year, influencing their knowledge and motivation. Secondly, trainers visit the teachers regularly to provide mentoring on the training, which affects teachers' knowledge and motivation, leading to new teacher practice. Lastly, active users of the training program re-share their experiences with the teaching community, thus positively influencing the teacher's knowledge and motivation.

7.3.1 Hypothesis

H1: Technology adoption will increase with community support.

Prior literature [147, 220] and my theory of change 7.4 led me to hypothesize technology adoption will increase. The extensive literature on asset-based design [147] recommends that users will be more inclined toward technology adoption, which has been demonstrated. From my theory of change 7.4, early adopters may use the conversational agent more and share its benefits with community members, thus compounding the benefits to improve motivation and knowledge in the community. Additionally, in Chapter 3, I learned that teachers highly appreciated the community support features in a pilot. Therefore, I expect to see improvement in adoption in the long data.

H2: Teacher motivation will increase with community support

Prior literature and my theory of change [7.4] led me to hypothesize that teacher motivation will increase when they are provided with community support by increasing their networks and sense of encouragement [8]. This change would be reflected in the increased agency in the community [196], increased self-efficacy in teaching [38], and reduced burnout [166]. Empirical data hints that teachers' agency towards career aspirations may increase by improved support networks [107, 100].

H2.1 *NewMethod* motivation will increase with community support

Prior literature and my theory of change [7.4] hint that teacher motivation for *NewMethod* may increase. Prior literature suggests that teachers' autonomy, competence, colleague support, and advisor support will increase with community support [20]. However, the scale for *NewMethod* motivation for the Ivorian context is being used for the first time. My work will help test the questionnaire for a new audience. From my theory of change 7.4, early adopters' interaction with community members will help provide improved competence and colleague support. Teachers' participation in discussion may also increase their sense of autonomy. Increased support from colleagues can reduce the dependence on advisors, leading to improved perceived advisor support. Therefore, I expect to see a change in *NewMethod* motivation in all the subscales.

H3: Teacher pedagogical knowledge and skills will increase with community support

Prior work and my theory of change led me to hypothesize that teachers' knowledge and skills will increase. Teachers will have more opportunities to discuss and learn from their colleagues when they have community support [5]. From my theory of change, active users will share resources with the community members, enabling knowledge sharing. Therefore, I expect to see improvement in knowledge and skills in the knowledge questionnaire.

H3.1: Teacher pedagogical knowledge will increase for active conversational agent users compared to inactive users

Unlike motivational components, pedagogical knowledge components on the conversational agent was common for all users. All users had access to the manual, tips and questions. Therefore, we hypothesize that users who use the conversational agent actively will show an increase in *NewMethod* pedagogical knowledge as compared to users who don't use the conversational agent.

7.4 Methodology

7.4.1 Study Design

To answer my research question [7.3], I conducted a large-scale longitudinal study in 2021-2022. I deployed the conversational agent to 126 schools across two regions (Region1 and Region2) in the Southwestern region of Côte d'Ivoire. Over 500 teachers were trained in *NewMethod* method and were implementing it for the first time. We followed a quasi-experimental approach to split teachers into two conditions (see Fig. 7.5) by region, i.e., (1) Community support in Region 1 and (2) Control in Region 2. Each region was given a different version of the chatbot.

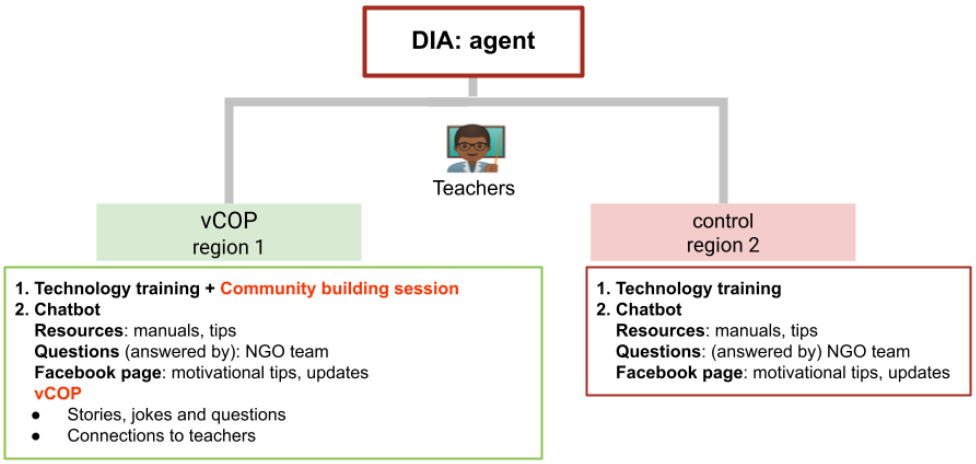

Fig. 7.5.: Study design consisted of two regions assigned to the two conditions, i.e., vCOP and control. The vCOP condition had features that supported a virtual community by allowing teachers to interact with each other. The vCOP technology training sessions included a community-building session. The control condition only had traditional chatbot features where teachers could access resources and ask questions about *NewMethod*

We followed a quasi-experimental design at a regional level to gain critical mass and avoid contamination. Prior social network research suggests the need for critical mass to support intervention adoption [106]. We also know from our data that teachers discuss with their communities through offline interactions. Therefore, we expect offline interactions in the teacher community could influence impact. For example, a teacher in a school may learn from the conversational agent and share information with fellow teachers, thus affecting their motivation and

knowledge. Secondly, we also wanted to avoid this re-sharing with the control group (contamination). Hence, we needed to choose schools sufficiently far from each other. Schools in regions 1 and 2 are 4 hours away through conventional travel, lowering the probability of group interaction. Before data collection, our local partners (IPA, NGO) supported our quasi-experimental design as they felt the regions were equivalent enough through their prior research and experience. After baseline data was collected, we discovered that the datasets for control and community conditions were equivalent. We found that as there was no statistical significance for relevant variables, such as gender, teaching grade, smartphone experience, and internet expenditure at baseline[A.4].

Control group (also referred to as individual support) had features to support teachers directly with the pedagogical programs. The conversational agent provided resources, question support, and connections to a Facebook page. The resources section included (a) Program manuals: PDFs with detailed information about different *NewMethod* activities for math and French, respectively; (b) Tips: short messages with relevant information from the manual. We also had question support, i.e., teachers could directly ask questions to the conversational agent. They received an immediate automated response from the agent or a delayed response from the NGO worker managing the system. Lastly, we connected the agent to the project's Facebook page. The research team and the NGO worker regularly posted motivational messages and updates related to the pedagogical program. More details about the design iteraction is in the section above [7.2].

vCOP group (also called community condition) had all the features in the Control group but also allowed teachers to connect with and support community members. We also added community-oriented features like stories and jokes valued in study 3. vCOP content enabled teachers to view and share content with community members. Teachers' contributions were moderated and curated by the NGO worker. Lastly, we added an experimental feature called the phonebook to provide connections to community members. A teacher's phone book connection had the teacher's name, school, and phone number, thus allowing the teacher to contact and form a new connection. More details about the design iteraction is in the section above [7.2].

Program Implementation

We trained the teachers to use the conversational agent through short workshops during *NewMethod* training. Our five teams visited 15 sites during the *NewMethod* training. *NewMethod* training occurred for a week, and a site had 10-50 teachers. Each group visited an area 1-2 times weekly to train and conduct conversational

Fig. 7.6.: These two pictures describe a sample training session held during study 3

agent workshops. First, for setup sessions, teachers were briefly introduced to the system features by a research team member. Then, the research team shared the Internet (through portable wifi) with teachers and guided them through the introductory tutorial section of the conversational agent. The setup session lasted for about an hour. After setup, we had practice sessions in which teachers used the various conversational agent features in small groups. The individual support condition had two general practice sessions, while the community support condition had one practice session and one community activity. Teachers discussed their stories in small groups during community activity and typed them digitally into the conversational agent.

Teachers were given a conversational agent training manual during the technology training. The manual had three pages of instructions on different features of the system. The training manual included a storyboard explaining the project and the conversational agent's role in supporting teachers. The manual explained the various features with illustrations and a few key points to navigate and then use the feature. The manual also contained the contact information of the local research team members. We modified the training material and structure based on the conditions.

Teachers in the vCOP condition received more instructions about community support features and a storyboard summarizing the same. Teachers in vCOP had a community-building exercise where they shared positive stories about teaching with fellow trainers. After sharing a few stories, teachers were instructed to browse through the conversational agent and read a few stories. Teachers were then requested to share their own stories on the conversational agent in small groups. Teachers in the vCOP condition had a version of the conversational agent manual that explained the community features and the different features specific to their version of the chatbot. The chatbot allowed teachers to continue sharing positive stories and had channels to maintain social connections with other teachers in the vCOP condition beyond the training.

Tab. 7.1.: Table summarizing the users distributed across different data sources. The last four rows represent the data sources used for analysis

Datasource	Total	Community condition	Control condition
All participants	518	284	234
All schools	126	67	59
All villages	82	48	34
All inspectorates	20	12	8
Chatbot users[7.5.1]	313	178	135
Motivation survey [7.5.2]	143	82	61
Knowledge survey [7.5.3]	91	51	40
Interviews	12	6	6

Beyond the training, teachers were sent regular reminders by text messages and on the Facebook page to motivate them to use the chatbot. Teachers who shared their numbers on the chatbot were sent SMS reminders with motivational messages throughout the year. We sent text messages during periodic events such as ASER tests, Christmas and Easter holidays. The NGO worker and the educational ministry moderated these text messages. We also shared motivational posts on Facebook every week, encouraging teachers to implement *NewMethod* and to ask questions on the chatbot. We shared pictures teachers shared on WhatsApp groups, showing examples of teachers working together for *NewMethod*. We also posted questions asking simple questions to engage the Facebook page. E.g., Did you plan an activity for the week? Which level did you teach? The NGO worker and a researcher managed the Facebook page.

Teachers were required to implement the *NewMethod* method daily as part of the ministry. Daily, 45 mins were allocated for Math activity and 45 mins for French. Teachers were required to implement *NewMethod* during free sessions in the official schedule, which were officially allocated for revision sessions. Teachers were not provided any financial incentives to implement *NewMethod*. Teachers were provided regular mentoring support by their pedagogical advisors and inspectors, who were also trained on *NewMethod*. Teachers also received visits from ministry officials and the NGO during the year. The administrators and NGO workers observed teachers implement *NewMethod* and provided them with constructive feedback.

7.4.2 Participants

The research was conducted in two regions in the Southern region of Côte d'Ivoire. The two regions comprised 20 inspectorates and 82 villages. There were 126 primary schools included for *NewMethod* training in two regions for the academic year. Our participants included teachers and directors from these 126 schools who

participated in *NewMethod*. *NewMethod* included teachers teaching in 3rd, 4th, 5th, and 6th-grade classes. After data cleaning initial pre-test surveys, we identified 518 participants in the program. There were 126 directors and 392 teachers who participated in the study.

The site had two regions that were allocated to community and control conditions. *Region 1* was allocated for the community condition. *Region 1* had 12 inspectorates and 48 villages. There were 67 schools in the region, and 284 participants were in these schools. *Region 2* was selected as control. There were 59 schools in this region. *Region 2* included 8 inspectorates and 34 villages. 234 participants were part of this region. The table 7.1 summarizes the data sources for the two regions.

The schools in these regions had challenges with infrastructure, which affected student literacy. A handful of urban schools were situated within the city, while the rest of the rural schools were scattered among outlying communities. The rural communities have limited infrastructure, notably lacking sufficient access to water, electricity, and reliable telephone signals. Moreover, these remote areas struggle with poor road conditions, which hampers travel and intensifies their seclusion. Consequently, students residing in these rural communities exhibit diminished literacy rates, shaped by the rural environment and inadequate infrastructure [121, 120]. To address these challenges, these regions were selected by the Ivorian education ministry and the NGO to improve education in rural Côte d'Ivoire [180].

7.4.3 Data Collection

Tab. 7.2.: Summarizes the different datasets for the research questions collected over the year.

Stage	Data	Research Questions
Baseline	September 2021	Collected baseline data for research
	baseline survey	DEMOGRAPHICS MOTIVATION
Mentor Training	October 2021	Trained 60 administrators to use the chatbot
Teacher Training	November 2021	Trained 400 teachers and directors to use the chatbot
	teacher training pre-test	KNOWLEDGE & SKILLS
	teacher training post test	KNOWLEDGE & SKILLS
	start chatbot deployment	CHATBOT ADOPTION
Midline	March 2022	Collected midline data for research
	phone survey	*NewMethod* MOTIVATION KNOWLEDGE
	teacher and director interviews	ALL
Endline	June 2022	Collected endline data for research
	endline survey	MOTIVATION *NewMethod* MOTIVATION KNOWLEDGE & SKILLS
	teacher and director interviews	ALL
	stop chatbot deployment	CHATBOT ADOPTION

The data for the study was collected through surveys, interviews, and log data during the academic year. The data was collected in five stages, and the table [7.2] summarizes the collected data and research questions.

Baseline data for this study was collected in September 2021 as part of the baseline survey for the longitudinal impact of unconditional cash transfers and educational-quality improvement in rural regions of Côte d'Ivoire [180]. Teachers teaching 3rd and 4th grade (CE1 and CE2) were selected from the 126 schools in the two regions. In a few cases, teachers were unavailable during data collection, and only one teacher was surveyed in these schools. The data was collected through an in-person survey by enumerators from IPA. The surveys contained questions on teachers' demographics and questionnaires to measure motivation. More details about these questions can be found in the next section [7.4.4] and the appendix table [A.4].

The *NewMethod* training session started with training administrators in October 2021. Administrators from each inspectorate were trained to *NewMethod* mentors. The administrators included a director, a pedagogical advisor, and an inspector. The mentors were trained to support teacher training in their respective inspectorates. The directors and pedagogical advisors led the training sessions in November. Beyond training the teachers on *NewMethod*, the mentor's role was to support teachers in implementing *NewMethod* for the following year. We trained the mentors on the conversational agent to receive their feedback and support in subsequent study phases.

In November 2021, the *NewMethod* training sessions allowed us to collect data on teachers' pedagogical knowledge and skills. Teacher pedagogical knowledge on *NewMethod* was collected two times during the week of the training session from all the teachers. The knowledge questionnaire was a multiple-choice questionnaire that was collected before the teacher training(pre-test) and after the training (post-test). More details about these questions can be found in the next section [7.4.4] and the appendix table [A.5].

We also deployed the chatbot during *NewMethod* training sessions for the teachers. The teachers were encouraged to use the chatbot at least once a week. The initial tutorial of the conversational agent involved answering demographic information such as name, phone number, region, school, etc. The demographic variable region information was used to alter the version of the conversational agent. All interactions with the chatbot were logged digitally in a cloud database. Facebook API provided a log of users every interaction with the chatbot, which was stored in a MySQL database.

Phone surveys and teacher interviews were conducted during the Midline phase in March 2022. Participants consisting of teachers and directors from the two regions were surveyed over the phone. Phone surveys were administered through a phone call by an Ivorian researcher. The survey had questions on teacher demographics, smartphone usage, and access, Facebook messenger and conversational agent usage, *NewMethod* motivation, *NewMethod* knowledge/skills questions (same as baseline), and general feedback on the conversational agent. Teachers and directors from both regions were also interviewed to understand the thesis research questions. The interviews were conducted in person and lasted for about 1 hour. The participants were interviewed by an Ivorian researcher with the protocol designed by the research team and the NGO. More details about the protocol can be found in the next section [7.4.4]

In June 2022, endline surveys and interviews were conducted after the school year. The survey was administered through a phone call by the IPA team. The same teachers surveyed in the baseline were selected for the survey in endline. Teachers' phone numbers collected during the baseline were used to contact them over the phone and administer the survey. Similar to the baseline, the endline survey had questions on teacher motivation but had additional questions for *NewMethod* motivation and teacher pedagogical knowledge than earlier stages. More details about these questions can be found in the next section [7.4.4]

7.4.4 Measures

MOTIVATION

To answer my research question on motivation, I had survey questions on perceived social support [82], teachers agency in the community [160], teacher self efficacy [175], teacher burnout [29] and teacher career aspirations [3].

Agency in the community consisted of 16 questions representing teachers' professional agency in their professional learning community [160]. This questionnaire was created and first validated with teachers in Finland [160], but has since been used on teachers in different contexts such as the US, New Zealand, China, and Taiwan. It consisted of subscales of representing *transformative practice* with four questions, *collective efficacy* with four questions, *positive interdependence* with three questions, *active help-seeking* with two questions, *proactive strategy* of 3 questions. All questions consisted of 5 options ranging from strongly agree to strongly disagree [160].

Self-efficacy: was inspired based on the self-efficacy questionnaire by Bandura [14]. The questionnaire consisted of 10 questions created specifically for teachers and tested in Syria and Germany [175]. The scale has been tested on teachers in different parts of the world, including Nigeria, China, and Israel. All questions consisted of a 5-option Likert scale ranging from strongly agree to strongly disagree [175].

Burnout: was measured using Maslachs burnout inventory [29] which consisted of 22 questions. The questionnaire consisted of *personal accomplishment*, *emotional exhaustion*, and *depersonalization*. A modified version of this scale intended for educators, tested on teachers in Cyprus, was used [104]. The scale has been tested on teachers in different parts of the world, including Ghana, the United States, and Scotland. This questionnaire required a numeric response on a scale of 7 [104].

Perceived social support consisted of 4 questions inspired by the 12 questions in the multidimensional scale of perceived social support [224]. This scale [224] was modified and validated on Chinese high school teachers [82] to understand support from colleagues, school principals, friends and family. This scale [82] was used in Greece, Colombia, and Hong Kong. Only four questions that were specific to colleagues [82] were used in our study. All questions consisted of a 5-option Likert scale ranging from strongly agree to strongly disagree [82].

Aspirations used two questions on *social norms* and two questions on *perceived agency* from the theory of planned behaviour [3]. These questions were not validated on aspirations and teachers before. All questions consisted of a 5-option Likert scale ranging from strongly agree to strongly disagree [3].

After data cleaning, 143 participants were present in two datasets collected at baseline and endline, which we used to analyze teachers' motivation [7.5.2].

NewMethod motivation:

To understand our research question on *NewMethod* motivation, a questionnaire on teacher motivation was adapted from prior work on teachers' motivation for work-related activities in China [111]. The questionnaire had questions about competence support, autonomy support, colleague support, and advisor support for *NewMethod*. More details about these questions are in the appendix table[A.6]. After data cleaning, 91 participants were present in the two datasets collected at midline and endline, which was used for analysis [7.5.2].

KNOWLEDGE & SKILLS

The NGO created the knowledge questionnaire to evaluate teachers on *NewMethod*. The knowledge questions comprised four sections of five questions for math, French, ASER test, and mentoring. The questions consisted of multiple-choice and true or false questions. More details about these questions are in the appendix table[A.5]. After data cleaning, 91 participants were present in the four datasets collected at midline and endline, which was used for analysis [7.5.3].

CHATBOT ADOPTION

The cumulative sum of interactions was used to analyze chatbot adoption. All participant interactions with the chatbot were logged digitally in a cloud database. I connected the different datasets by creating a unique identifier for each user (PRIMARY_ID). I used the unique identifier to connect datasets to the chatbot logs and baseline. Using this connection, I could allocate the total number of messages sent to the chatbot for every user. A threshold of this variable was used to create two sub-datasets, i.e., active chatbot users and inactive chatbot users. Active chatbot users were set as users who sent over 33 messages to the chatbot or users who used the chatbot after the training. These measures were used for future analysis [7.5.1].

Interviews

We conducted in-depth interviews with teachers during the middle and end of the year. Schools for this sample were selected based on recommendations by the inspector. Our interview protocol had questions to discover (1) conversational agent perceptions and barriers to usage, (2) the influence of *NewMethod* or technology on teachers' aspirations, (3) *NewMethod* support from colleagues and trainers, (4) *NewMethod* knowledge access and barriers. Interviews lasted for 45 minutes; they were conducted in schools or towns near the school. Twelve teachers (2 directors, 10 teachers) were interviewed during midline and endline. Teachers were equally distributed across both regions. The US research team designed the protocol, but the NGO and the Ivorian research team contextualized the questions for the participants.

7.4.5 Data Analysis

Difference-in-Differences

$$Y = \beta_0 + \beta_1 * g + \beta_2 * t + \beta_3 * (t * g) + \sum_{i}^{n} \beta_{i+3} * Covariate_i + \epsilon \tag{7.1}$$

I used the standard difference-in-differences [35, 69] equation 7.1 in regression form. g is the group variable; 1 was used for the community support condition, and 0 was used for the individual support condition. t is the variable used to indicate the start of the treatment; data in the baseline had 0, while data in the endline had 1. β_3 is the difference in differences that is obtained after the regression. β_i is the coefficient for the different numeric and categorical covariates used in the study. This equation was used for teacher motivation[7.5.2] and teacher pedagogical knowledge[7.5.3].

Covariates The datasets for individual and community support conditions were equivalent, as there was no statistical significance for relevant variables, such as gender, teaching grade, smartphone experience, and internet expenditure at baseline[A.4]. Therefore, no covariates were used for Motivation[7.5.2]. For Knowledge[7.5.3], *time in weeks* was used as an additional covariate as there were four different data points. The errors were clustered by village and school level.

Analysis variables - A1 and A2

Treatment effect estimates are typically conservative because noncompliance numbers dilute the data. There, we were interested in exploring an as-treated analysis; that is, we would like to investigate what happens when participants receive the benefits of the community interaction, which includes only those who were active users of the community version, compared to those who do not receive the benefits of the community condition.

I used the log data to create two exploratory analyses for understanding the effects on motivation and knowledge from active chatbot users. The first analysis variable (A1) to help understand the motivation[7.5.2] hypothesis. A1 analysis consisted of active users in vCOP who used the community features and all users in the control condition. Treatment effect estimates are typically conservative because noncompliance numbers dilute the data. There, we were interested in exploring an as-treated analysis; that is, we would like to investigate what happens when participants receive the benefits of the community interaction, which includes only

those who were active users of the community version, compared to those who do not receive the benefits of the community condition (i.e., control users).

The second analysis (A2) was used to understand the knowledge[7.5.3] hypothesis. A2 was used for comparing all active users, i.e., users who used the conversational agent and inactive users. From my theory of change, active users learn from the chatbot, enabling improved pedagogical knowledge. Since instruction from the chatbot was common to users in both conditions, the A2 analysis compared active and inactive users to understand the knowledge questions. The analysis variables A1 and A2 were inspired by instrumental variable [69] analysis in the economics literature. Instrumental variables help understand the effect of treatment-on-treated when there is differential use of the intervention, such as technology adoption.

Simple matching

Simple matching or average treatment effect [145] was used in chatbot adoption[7.5.1] and *NewMethod* motivation[7.5.2]. This method uses the average treatment effect (AT) and compares the distributions to derive a p-value. This approach was used when there was no baseline data, which was the case for chatbot adoption and *NewMethod* motivation.

Chatbot adoption[7.5.1]: The log data provided the cumulative number of messages sent over the year for every participant. The cumulative messages were used as the usage variable for analyzing chatbot adoption. The average net usage across the two regions from 143 users in the endline survey was used for analysis.

NewMethod motivation[7.5.2]: A numeric value was assigned to the individual answers from the Likert scale. The net motivation for each category, i.e., competence, autonomy, colleague support, and advisor support, was used for the analysis. The questionnaires in the midline and endline had different Likert scales (5 vs. 7), so we used a Z score for equivalence of the two conditions. We could not collect baseline data because teachers did not know about *NewMethod* before the teacher training.

Qualitative Analysis

We used qualitative analysis to analyze the (1) interviews and the (2) conversational agent log data.

We combined the interview data from both stages into a single data set. We transcribed and translated the interview data into English. I went through the transcripts and formed the codes using an inductive approach [36, 188, 134, 25]. I then considered the relationship between the codes and categorized them according to the main research questions. Some codes were "aspirations: internet helps, aspirations: WhatsApp study group helps". I then discussed the codes and the quantitative results with my research collaborators and modified the codes based on our discussions. Some final codes were "aspirations: tech literacy is helpful for exam preparation," and "aspirations: latest child development is help for career". These codes were then edited to improve the readability for answering the research question and reported in the sections.

The questions and stories shared by the participants were categorized from the chatbot log data. Codes for the log data were generated inductively from their respective datasets. Each type of data was cleaned and transferred to a spreadsheet. We translated the questions from French to English and then annotated them into codes, e.g. (Math activity: jump, *NewMethod* operations). These codes were categorized based on the type, i.e., *document: 2 digits in math*, *document: bulletin visit* was classified into "Document". When the datasets were small, i.e., we couldn't generate categories due to the limited number of codes, the initial codes were used as categories.

7.4.6 Self-disclosure

Our team consists of HCI researchers, economists, and linguists. Our experience, approach, and goals will affect the data analysis. We are based in North America and Côte d'Ivoire and have conducted research in various developing regions. Our approach was similar to our prior work in Study 2 [30]. Additionally, our goal with the future study is to evaluate the effects of quality education (conversational agent and *NewMethod*) on students at scale. The long-term goal of our project is to support teachers with low-cost technology to implement the pedagogical program.

7.5 Findings

7.5.1 CHATBOT ADOPTION

Using simple matching, we found that teachers in the community condition sent more messages than individual support, but the results were not statistically sig-

Tab. 7.3.: Summarizing technology adoption across the two conditions

variable	Avergage difference	p value	community endline	control endline	community active endline	control inactive endline
chatbot usage (messages)	8.128	0.168	33.42	25.30	61.84	4.33
reported chatbot usage	-0.724	0.597	3.89	4.60	5.72	2.00

nificant. On average, teachers in the community condition sent 33.6 messages compared to 25.6 in the control condition. The difference was 8.12 messages (p=0.17). Active users sent 61.83 messages, and inactive users sent 4.33 messages.

The self-reported usage was higher in the control condition, 4.6 vs. 3.9 in the community region, but this difference was not significant (p=0.597). The reported usage was recorded on a Likert scale that converted the responses to the frequency of messages in a month. For example, a response of 30 indicates daily usage, and a response of 4 indicates weekly usage. Among active users in the community region, the reported average usage was 5.72; among inactive users, the reported average usage was 2.

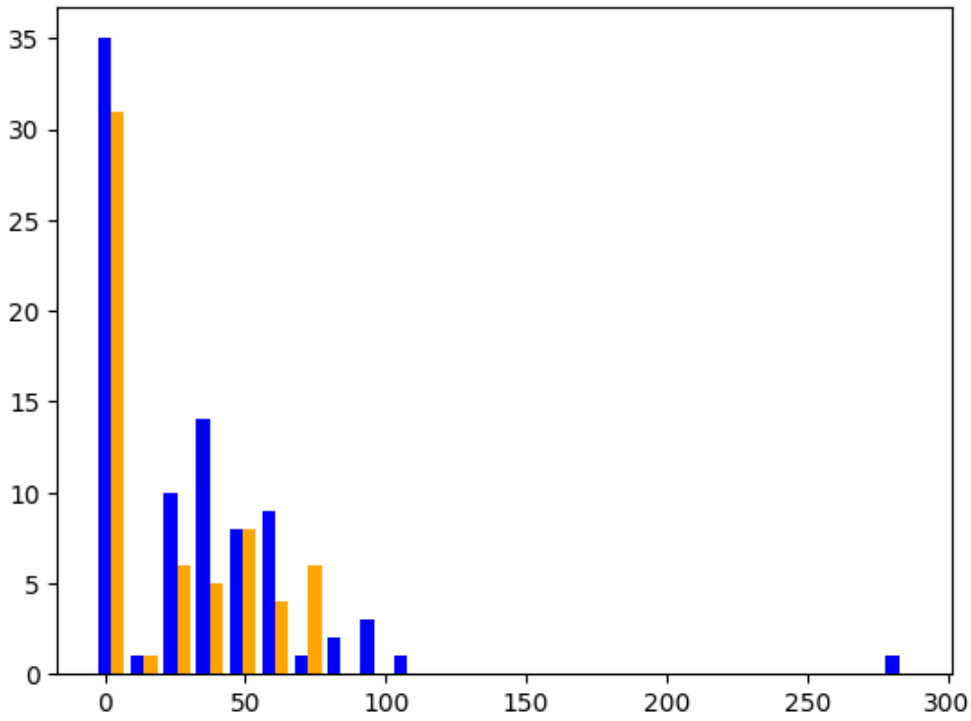

Fig. 7.7.: showing a comparison between the two conditions. Blue is community support, and orange is individual support.

We identified 110 participants from the baseline survey who registered on the conversational agent. Only 80 out of these 110 participants sent messages to the conversational agent. Thirty users registered on the conversational agent but did not finish the initial survey to start using it. The 80 users sent an average of

55.39 messages, ranging from 22 to 292 messages over the year. Fig 7.7 shows the distribution of user messages in the community and the control condition. Users in the community condition sent an average of 33 messages, while those in control condition sent an average of 25, but the changes were not statistically significant. Lastly, the logs could not identify 38 users from the baseline survey. Our survey data tells us that 26 users did not have smartphones. Twelve users could not be adequately identified or did not participate in the study[1]..

7.5.2 MOTIVATION

Tab. 7.4.: Shows the differences in differences and analysis variable(A1) for the various scales in motivation. 143 teachers were present in 2 datasets collected at baseline and endline.

	community condition (n=82)		control condition (n=61)		community vs control			(A1) active community vs control		
variable	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	didi (%)	p value	q value
perceived social support	82.9	82.7	83.1	78.4	4.2	0.2	0.276	7.4	0.079	0.125
self efficacy	84.9	81.5	83.2	81.2	-1.6	0.316	0.348	-0.8	0.67	0.67
agency: transformative practice	86.9	89.6	88.7	87.7	4.2	0.175	0.275	9.7	0.012	0.06
agency: collective efficacy	87.9	91.4	91	89.8	3.8	0.157	0.275	5.4	0.141	0.194
agency: positive interdependence	88.5	94.8	94.3	93.2	5.9	0.028	0.151	8.4	0.041	0.099
agency: active help seeking	86.3	91.8	90.5	91.6	5.5	0.08	0.193	8.1	0.073	0.125
agency: proactive strategy	86	92.7	91.5	89.4	6.9	0.026	0.151	10.9	0.006	0.06
agency: combined	87.2	91.9	91.1	90.1	5.1	0.041	0.151	8.4	0.016	0.06
burnout: personal accomplishment	95.7	95.6	93.2	96.4	-2.3	0.251	0.307	-2.1	0.313	0.344
burnout: emotional exhaustion	33.8	35.3	31.4	34.3	-3.4	0.088	0.193	-4.6	0.045	0.099
burnout: combined	-27	-25.5	-27.7	-26.9	-1.9	0.412	0.412	-3.2	0.206	0.252

did (%) indicates difference in differences in percentage.
p value <0.05 is considered significant, p value < 0.01 is considered marginally significant.
q value is the FDR corrected p value using Benjamini Hochberg correction.

The appendix table A.3 provides more information on invalid scales and confidence intervals.

Perceived social support: There was a positive change over time for *perceived social support* scale in the community condition compared to the control, but the results were not significant (difference-in-difference: 4.2 %, p=0.2). An exploratory analysis of the comparison between active users in the community condition and all users in the control condition (A1 analysis) showed a positive change over time, and the change was marginally significant (difference-in-difference: 7.4 %, p=0.079).

Self efficacy: There was a negative change over time for *self-efficacy* in the community condition compared to the control condition, but the change was not significant (difference-in-difference: -1.6 %, p=0.316).The average endline for *self-efficacy* for both conditions reduced compared to the average baseline, indicating that teachers self efficacy dropped at the end of the academic year. An exploratory analysis (A1) comparing active users in community and the control users showed a negligible

[1]Note: 5 participants from the baseline could not be surveyed due to their unavailability at the endline, so we have 143 users in the final dataset

negative change over time, but the results were not significant (difference-in-difference: -0.8 %, p=0.67).

Agency in the community: There was a significant positive change over time in the *combined agency* in the community condition compared to the control (difference-in-difference: 5.1 %, p=0.041). The average endline for *combined agency* for community condition increased compared to its baseline, while the average endline for control condition reduced compared to its baseline. We also observed significant positive changes over time for some sub-scales of agency for the community condition. We observed significant positive change over time for the *positive interdependence* (difference-in-difference: 5.9 %, p=0.028), and *proactive strategy* (difference-in-difference: 6.9 %, p=0.026) for the community condition as compared to the control condition. The other sub-scales in agency showed a positive change over time (difference-in-difference: 7% to 4%), but the results were not significant. An exploratory analysis of the comparison between active users in the community condition and the control condition (A1 analysis) showed significant positive change over time for *combined agency* and some of its subscales. For active users, there was a significant positive change over time in *combined agency* for the community condition compared to the control condition (difference-in-difference: 8.4 %, p=0.016). Like community vs. control, we observed a positive change over time for the subscales of *combined agency* for active users in community vs. control. We observed a positive change over time for *transformative practice* (difference-in-difference: 9.7 %, p=0.012), *proactive strategy* (difference-in-difference: 10.9 %, p=0.026), and *community interdependence* (difference-in-difference: 8.4 %, p=0.041). The other sub-scales in *combined agency* also showed a positive increase over time for active users, but the results were not significant.

Burnout: There was a negative change over time in the *combined burnout* scale in the community condition compared to the control, but the difference was not significant (difference-in-difference: -1.9 %, p=0.412). The negative change in *combined burnout* indicates that teachers in the community condition exhibited less burnout than the control. Examining the burnout subscales, we observed a negative change over time for *personal accomplishment*, but the results were not significant (difference-in-difference: -2.3 %, p=0.251). We observed a negative change over time for *emotional exhaustion* in the community condition and the results were marginally significant(difference-in-difference: -3.4 %, p=0.088). The reduction in *personal accomplishment* indicates increased burnout in the community condition compared to the control condition. On the other hand, the reduction in *emotional exhaustion* indicates decreased burnout in the community condition compared to the control condition. The reduction in *emotional exhaustion* contributes to the overall change in the *combined burnout* questionnaire.

An exploratory analysis of the comparison between active users in the community condition and all users in the control condition (A1 analysis) showed a negative change over time for *combined burnout*, but the results were not significant (difference-in-difference: -3.2 %, p=0.206). For A1 analysis for sub-scales of burnout, we observed a decrease over time for *personal accomplishment* indicating increased burnout for active users, but the results were not significant (difference-in-difference: -2.1 %, p=0.313). Interestingly, we observed an increase over time for *emotion exhaustion* for active users as compared to the control condition (difference-in-difference: -4.6 %, p=0.045). The increase in *emotional exhaustion* indicates reduced burnout for active users as compared to control, and the results were marginally significant.

The Cronbach alpha for *depersonalization* in burnout was low (0.23) [A.2], indicating that the scale is not valid in the context and hence was discarded in the *combined burnout*.

Exploratory error correction for motivation: We used False Discovery Rate (FDR) for an exploratory error correction to adjust p-values to q-values using Benjamini Hochberg correction [23]. FDR controlling procedures provide a less stringent error rate compared to the Bonferroni correction when there are multiple tests [23]. The set of p-values for community vs. control was corrected using the FDR function to obtain the corrected q-value.

We used a similar FDR correction to adjust the p-values for the A1 analysis. All adjusted q-values for p-values with significance reduced to marginal significance. For *perceived social support*, the p-value reduced from marginally significant(p=0.079) to an insignificant result(q=0.125).

Aspirations: The Cronbach alpha for both the scales for aspirations was very low (0.07 for *aspirations: social norms* and 0.373 for *aspirations: agency*) [A.2], indicating that these scales were not valid instruments in the context. Therefore, we discarded the two scales for motivation analysis. To understand the change in aspirations, we instead looked at individual questions, reported in table [7.5].

We observed changes for community vs. control comparisons, but only one scale showed marginal significance. For *social norms: superior approval*, we observed a negative change over time for the community condition compared to the control condition, but the results were not significant (difference-in-difference: -3.3 %, p=0.249). For *social norms: successrate*, we observed a positive change over time for the community condition compared to the control condition, and the results were marginally significant (difference-in-difference: 10.2 %, p=0.066). For *agency: success confidence*, we observed no change change over time for the community condition compared to the control condition (difference-in-difference: <0.001 %,

p=0.997). For *agency: success self-reliance*, we observed a negative change over time for the community condition compared to the control condition, but the results were not significant (difference-in-difference: -5.1 %, p=0.144).

Tab. 7.5.: Table summarizing responses for individual questions in the aspirations scale. 143 users were used for comparison in the two datasets collected in baseline and endline.

	community condition (n=82)		control condition (n=61)		community vs control			(A1) active community vs control		
variable	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	didi (%)	p value	q value
social norms: superior approval	85.2	80.7	81.9	80	-3.3	0.249	0.332	-2.3	0.466	0.622
social norms: successrate	52.8	58.4	64.1	54.9	10.2	0.066	0.262	11.8	0.065	0.258
agency: success confidence	78.7	76.5	74.3	74.5	0	0.997	0.997	-0.5	0.933	0.933
agency: success self-reliance	79.8	80.8	78.7	78.9	-5.1	0.144	0.287	-3.2	0.416	0.622

did (%) indicates difference in differences in percentage.
p value <0.05 is considered significant, p value < 0.01 is considered marginally significant.
q value is the FDR corrected p value using Benjamini Hochberg correction.

An exploratory comparison (A1) between active users in the community condition and all users in the control condition showed similar results. Although we observed changes in all questions, only the difference in *social norms: successrate* was marginally significant. In A1 analysis for *social norms: successrate*, we observed a positive change over time, and the difference was marginally significant (difference-in-difference: 11.8 %, p=0.065). In A1 analysis for *superior approval*, we observed a negative change over time, and the difference was not significant (difference-in-difference: -2.3 %, p=0.466). The two questions for *agency* showed a negative change over time for A1 analysis (difference-in-difference: -1.8 %, p=0.61), but the results were not significant.

Error correction for aspirations: We used False Discovery Rate (FDR) error correction to adjust p-values to q-values using Benjamini Hochberg correction [23]. All adjusted q-values did not retain significance. We expect this was the case due to low statistical power in the data.

NewMethod motivation

Overall, we see increased motivation for community condition compared to the control for all the motivation subscales for *NewMethod*, but the results were insignificant. Since we used simple matching, we report this *NewMethod* motivation component's observed net change. For the community condition, we observed improvements in all scales of motivation. We saw positive changes in *NewMethod competence* (Average change: 5.23%, p=0.360), *NewMethod autonomy* (Average change: 1.58%, p=0.832), *NewMethod colleague support* (Average change: 1.89%, p=0.682), and *NewMethod advisor support* (Average change: 10.15%, p=0.094). Only advisor support was marginally significant, while the other components

Tab. 7.6.: Table summarizing average *NewMethod* motivation responses. 91 users were used for comparison in the two datasets collected in midline and endline

variable	community vs control Average change%, p-value	active community vs control Average change%, p value
NewMethod competence	5.23%, p=0.359	7.85%, p=0.214
NewMethod autonomy	1.58%, p=0.831	-2.27%, p=0.788
NewMethod colleague	1.89%, p=0.682	2.27, p=0.652
NewMethod advisor	10.15%, p=0.094	10.41%, p=0.112
Motivation (combined)	4.71%, p=0.306	4.56%, p=0.371

Average change (%) indicates the average change in percentage after comparing the means of the two conditions.
p value <0.05 is considered significant, p value < 0.01 is considered marginally significant.

were not significant. An exploratory comparison (A1) between active and control users in the community showed similar changes, but the results were not significant. We observed improvements for active users in the community condition for *NewMethod competence* (Average change: 7.85%, p=0.788), slightly improved *NewMethod colleague support* (Average change: 2.27%, p=0.652), and a large gain in *NewMethod advisor support* (Average change: 10.41%, p=0.112). However, all these changes were not significant. Additionally, unlike community vs. control, there was a decrease in *NewMethod autonomy* for active users (Average change: -2.27%, p=0.788), but the changes were not significant.

7.5.3 KNOWLEDGE & SKILLS

Tab. 7.7.: shows difference-in-differences and analysis variable(A2) for various components of the knowledge questionnaire. 91 teachers were present in 4 datasets collected at pre, post, midline and endline.

	community condition (n=51)		control condition (n=40)		community vs control			(A2) all active vs inactive users		
variable	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	didi (%)	p value	q value
french	33.8	47.7	32.9	52.5	4.8	0.319	0.946	-1.8	0.724	0.772
math	47.3	75	46.2	75	-0.6	0.899	0.946	1.5	0.772	0.772
aser	27.7	67.7	26.2	68	-0.7	0.88	0.946	9.9	0.035	0.176
mentor	55.8	75.8	57.6	80	-0.4	0.946	0.946	1.8	0.75	0.772
knowledge	41.2	66.6	40.7	68.9	0.8	0.786	0.946	2.8	0.361	0.772

did (%) indicates difference in differences in percentage.
p value <0.05 is considered significant, p value < 0.01 is considered marginally significant.
q value is the FDR corrected p value using Benjamini Hochberg correction.

There was no significant change over time for *combined knowledge* in the community condition compared to the control condition (difference-in-difference: 0.8 %, p=0.786). Examining individual categories, we observed a positive change over time for *French* (difference-in-difference: 4.8 %, p=0.319), but the results were not significant. We observed negligible changes over time for other categories compared

to the control. Furthermore, we observe that the endline for control is higher than the community condition, indicating the effect of time influencing the knowledge change for each component. The influence of time can be observed in the figure in the Table [A.4]. Although teachers in the community condition learnt more in the initial stages, the knowledge decay was faster in the community condition.

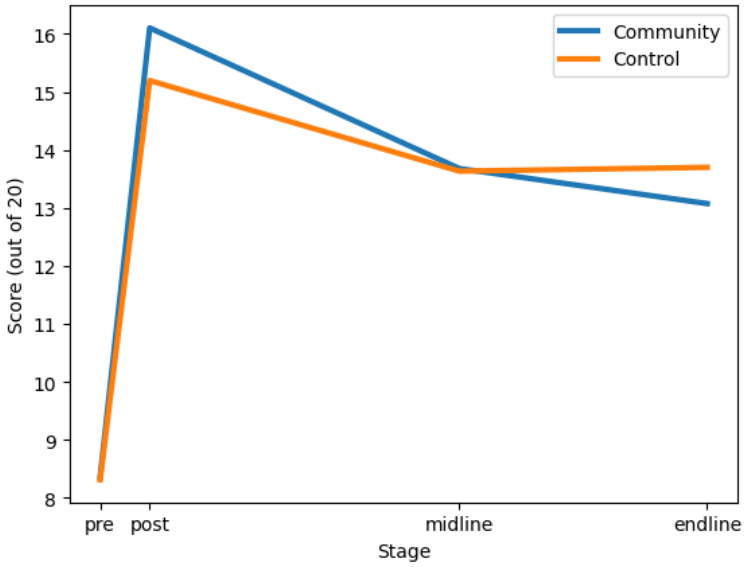

Fig. 7.8.: Trend of questions for overall knowledge throughout the year 7.5.3

We ran an exploratory analysis of all active vs. inactive users (A2) to understand the effect of conversational agent usage on teachers' knowledge. The features for *NewMethod* knowledge in the conversational agent were the same in both conditions; hence, users were divided based on their activity to understand the effect of conversational agent usage on pedagogical knowledge. For A2 analysis, there was a positive change over time for *combined knowledge* among active users, but the results were not significant (difference-in-difference: 2.8 %, p=0.361). Examining individual components for A2 analysis showed a significant change only for the ASER component. We observed a significant positive change over time for the *ASER* component (difference-in-difference: 9.9 %, p=0.035) for active users compared to inactive users. The *math* category showed a positive change over time for A2 analysis, but the results were not significant (difference-in-difference: 1.5 %, p=0.772). The *mentoring* category also showed a positive change over time for A2, but it wasn't significant (difference-in-difference: 1.8 %, p=0.75). There was a negative change for active users in the *French* category during A2, but the change was not significant (difference-in-difference: -1.8 %, p=0.724). The A2 change for French was contrary to community vs. control, which had increased over time.

Exploratory Error correction for knowledge: We ran a False Discovery Rate (FDR) correction to adjust p-values using Benjamini Hochberg correction [23]. The set of p-values for control vs. community was corrected using the FDR function. All corrected q-values were reduced and were not significant. We ran a similar FDR correction to adjust the p-values for the A2 analysis. All p-values decreased and were not significant.

7.5.4 CHATBOT USAGE

Beyond impact, we were interested in understanding chatbot usage to derive insights for our hypothesis [7.5.2, 7.5.3,7.5.1]. This section discusses how all participants (313) used the different features of the chatbot over the year. We later use findings from this section in the discussion section to explain our quantitative results.

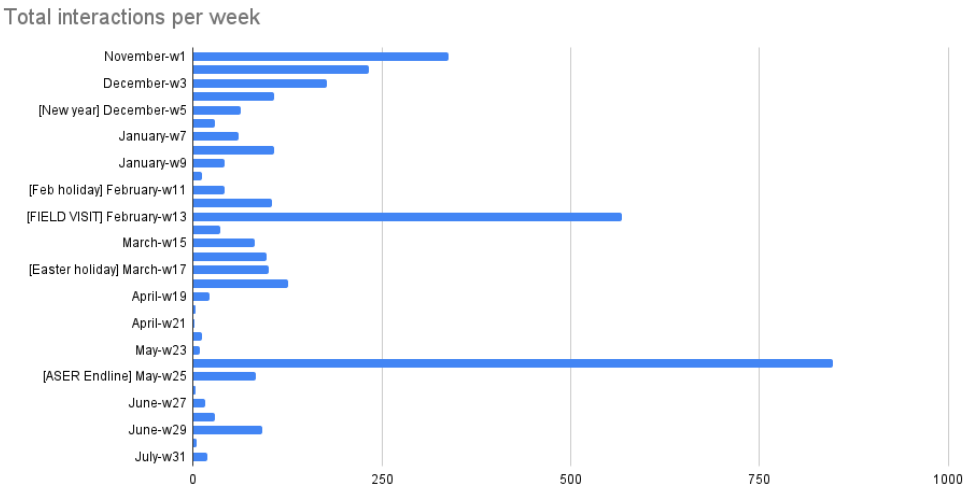

Fig. 7.9.: Shows the total number of weekly messages by 313 teachers.

Teachers sent 111 messages (standard deviation: 179) per week throughout the 30-week deployment (see Fig 7.9). These messages include questions and menu interactions, which include reading other teachers' stories, reading tips, and downloading manuals. The top weeks of activity were during the 3rd week of February and the 3rd week of May. The active weeks of usage overlapped with the field visits of the research team when teachers were quizzed about their chatbot usage. We also see high use during ASER tests, i.e., student evaluation conducted by the teachers in baseline, midline, and endline. The ASER tests were an essential part of *NewMethod*, and teachers had to test all students to group them into *NewMethod*

levels. In interviews and log data, teachers asked questions about ASER tests. In interviews, teachers mentioned that they needed help during ASER tests and would seek help from the conversational agent. Teachers also used the chatbot during holidays when school was closed. We see from our chatbot logs (see Fig 7.9) that teachers sent greeting messages, sending seasonal greetings to the chatbot for Christmas and Easter (*Happy Easter to you DIA*). In interviews, teachers mentioned that they visit towns during holidays where they have good internet connectivity, and they could send messages to the chatbot.

CHATBOT USAGE: QUESTIONS

Tab. 7.8.: showing the percent of total questions answered by the HUMAN (NGO worker) and the chatbot

	BOT ANSWERED	HUMAN ANSWERED	ALL ANSWERED	UNANSWERED	TOTAL
Total questions	65	204	208	47	255
Percent	25.49	80	81.57	18.43	

Teachers asked 255 questions over the year. Most of the questions (81.57%) were answered by the NGO worker or the chatbot. Table 7.8 summarizes the questions provided by the NGO worker(Human Answered), chatbot, and unanswered questions. The conversational agent answered 65 questions immediately when the question was similar to a question in the database (see Table 7.10). The database was created from a prior set of teachers' questions related to *NewMethod* (Study 3). The conversational agent answered simple interactions such as greetings and basic information about the teaching method. When the question was in the database, the conversational agent provided automated answers immediately. When the question was not in the chatbot's database, it responded that it would get back to teachers shortly. The NGO worker responded to questions using a web-based interface that highlighted the unanswered questions in red. The red highlight was changed to green upon answering, and the answer provided was displayed (see Fig A.5 in the appendix). The NGO worker answered 204 out of 255 questions (80%). The NGO worker responded to queries related to *NewMethod* activities, session planning, and ASER tests. Together, the chatbot and NGO worker answered 208, i.e., 81.57% of all questions. Only 47 questions were unanswered (see Table 7.11). The unanswered questions consisted of errors and queries beyond the NGO worker's scope.

Tab. 7.9.: showing different codes answered by the HUMAN (NGO worker)

CODE	COUNT	PERCENT
GREETING	39	26.7
OTHER	24	16.4
ASER	17	11.6
FRENCH ACTIVITY	17	11.6
SESSION PLAN	14	9.6
CLASSROOM MANAGEMENT	7	4.8
MANUAL	7	4.8
NewMethod INFO	3	2.1
NewMethod IMPLEMENTATION	3	2.1
DIA INFO	7	4.8
MATH ACTIVITY	5	3.4
NewMethod PHILOSOPHY	3	2.1
TOTAL	146	

CHATBOT USAGE: HUMAN ANSWERED

After data cleaning and merging, there were 146 unique questions that the NGO worker answered. Table 7.9 summarizes the 146 unique questions answered by the NGO worker. The paragraphs below summarize the different categories of questions answered by the NGO worker.

The most popular category was *French activity* (11.6%). Teachers asked questions about implementing a specific French activity and queries about modifying an existing activity for their context. For implementing activities in French, teachers asked for information about specific activities in the French manual. *How to implement the "bingo game" with the letters? - Q27* and *Please, how to conduct "activity of words"?. - Q116.* Additionally, teachers asked questions about modifying a specific French activity. Some teachers mentioned that they had challenges implementing an activity to teach part of the curriculum *Hello, I would like to discuss the Phonetic-Syllabic painting. The sounds of consonant combinations like BR are missing in this painting: BL; Fr; FL; PL; Pr; Dr - Q17*

The next popular category was *ASER* (11.6%), where teachers asked about ASER test implementation. ASER tests were conducted by teachers three times during the year, comprising a baseline, midline, and endline for students. ASER tests were used to group students into levels based on their performance. Teachers asked questions about (1) Grouping students after the ASER test. Teachers asked questions when they found students who did not fit the traditional *NewMethod* classes. (*Where to classify the students who do not recognize the numbers but manage to divide? - Q14*). Teachers also asked questions about (2) specifics of ASER implementation. For example, teachers were interested to know if they should use the same

instrument for baseline and midline for a particular student (*Should we use the same number of the Aser tool for the student in this mid-term? - Q70*). Lastly, teachers asked questions about (3) the different documents to implement and record the ASER test - (*I want to know how to complete the Aser end test document?. -Q77*)

Teachers also asked about preparing a session plan (SESSION PLAN: 9.6%), a document for the weekly activities about *NewMethod*. Teachers requested information about official session plan documents. For example, teachers were interested in the official example documents activities for *NewMethod*- (*Give me an example of a weekly session plan - Q41*). The example session plans were generic, and teachers were encouraged to modify them for their *NewMethod* class levels. Teachers also asked specific questions about altering their session plan for a particular level of students (*How to prepare your session plan in words /paragraph?* - Q26.)

Teachers requested the digital version of the *NewMethod* manuals (MANUAL: 4.8%). There were official documents in Math and French for *NewMethod*, which explained the different activities and provided instructions to implement them. Each teacher was given a physical copy of these manuals after training. Teachers mentioned in interviews that they would forget to carry the physical manuals while traveling, so they used the chatbot to access the digital versions. These digital manuals were also present in existing menus in the conversational agent, further augmenting its importance for the teachers.

Teachers asked fewer questions in Math than in French even though they were supposed to implement both subjects daily (11.6% for French vs. 3.4% for Math). Math questions were about implementing a specific Math activity, and a few questions were about specific issues about a particular activity. Teachers asked questions about using the materials for *NewMethod* activities in math. - *How to start the "rod activities" course in mathematics? - Q47*. For specifics, teachers asked questions about implementing activities by class level - *What activities are planned in mathematics at the subtraction and division level - Q107*.

The remaining categories included information about the program's teaching program(*NewMethod* INFO, *NewMethod* PHILOSOPHY) and chatbot (DIA INFO). Teachers were interested in knowing more about the *NewMethod* program and how *NewMethod* was performing in other countries (*Can you tell us about the experiences of NewMethod in other countries? - Q118*). Teachers asked questions about the objective of the *NewMethod* program (*What is the objective of the NewMethod? - Q34*). For the chatbot (DIA INFO), teachers were curious about the system's aim (*What is the particularity of DIA - Q21*). The other question in this category was accessing system features (*How to access the NewMethod Facebook page. - Q9*) or (*How long is the NewMethod page open - Q254*).

Finally, the last category consisted of questions that were text providing feedback about the *NewMethod* program (16.4% (OTHER). The input included stories, jokes, and goals wrongly categorized as questions. The stories described teachers' positive experiences (*During a NewMethod lesson on the sticks. Usually, traditionally inactive students became highly active and could answer all their questions - Q49.*). Additionally, there were traditional teaching questions outside the *NewMethod* program's scope (*What is the lesson's objective in multiplication at CE1 - Q80*). The NGO worker responded that the system only supports questions about *NewMethod*.

Tab. 7.10.: showing different codes answered by the chatbot for 65 questions.

CODE	COUNT	PERCENT
GREETING	55	84.6
PEC ACTIVITY	3	4.6
DIA INFO	2	3.1
ASER INFO	2	3.1
PEC INFO	2	3.1
SESSION PLAN	1	1.5
TOTAL	65	

CHATBOT USAGE: BOT ANSWERED

Most of the questions that were answered by the bot (see table 7.5.4) were greetings (84.6%), and some were basic information about *NewMethod* or the chatbot. (GREETINGS 84.6%) It is customary in the Ivorian culture to greet people before starting any conversation (*Good evening Dia, Good evening, madam*). The cultural phenomenon of greeting was incorporated into the chatbot designs. Greetings initiated conversations with the chatbot, leading the user to the home menu. (*NewMethod* activity - 4.6%) The next category the chatbot was able to answer was about implementing various *NewMethod* activities that were recorded in the chatbot's database (*How to make the activity jump on numbers?*). (*NewMethod* INFO: 3.1%) The chatbot also provided information about the *NewMethod* program's objective and ASER tests (*What are the objectives of NewMethod?*). (DIA INFO: 3.1%) The chatbot also gave information on questions about itself (*What does chatbot mean?*) and guided teachers in using specific features of the chatbot (*I want access to the Facebook page?)*

CHATBOT USAGE: UNANSWERED

The major category of unanswered questions was requests for administrative documents (DOCUMENT 23.4%). The *NewMethod* program had documents beyond the

Tab. 7.11.: showing different codes left unanswered by the NGO worker and the chatbot.

CODE	COUNT	PERCENT
DOCUMENT	11	23.4
SHORT ACKNOWLEDGMENT	8	17
STORY	7	14.9
ERROR	6	12.8
MATH ACTIVITY	6	12.8
FINANCIAL	2	4.3
FRENCH ACTIVITY	2	4.3
DIA OBJECTIVE	2	4.3
SESSION PLAN	2	4.3
REQUEST	1	2.1
TOTAL	47	

NewMethod manuals, such as mentor visits. Teachers requested these documents by asking the chatbot (*An example of a "Visit Bulletin" of a NewMethod class)*. The NGO worker often didn't have access to the digital version of the documents, which may have led her not to answer these categories. The next category was (SHORT ACKNOWLEDGMENTS 17%). When teachers responded to prior questions, some acknowledgments were (*OK and OK, that works*). These very short acknowledgments were tagged as questions. (ERROR 12.8%) The next set of questions were errors: chatbot internal commands were wrongly tagged as questions. (STORY 14.9%) Teachers entered stories partially, and the system detected it as a question (*I am M kaba, facilitator, I went to my grandfather's*.). The NGO worker may have seen the complete response in the subsequent response, which may have led her not to answer.

The next set of questions was about *NewMethod* Activities. There were more unanswered questions in Math than in French. The NGO worker specialized in French so she may have answered more questions about her expertise. The questions for math activities (MATH 12.8%) included questions about conducting different math activities (*How to conduct a multiplication session with children's currency?*). The questions in the French category were fewer and were on two separate activities (informal dialogue and image description).

The final categories were about *NewMethod* program operations, i.e., program objectives and requests. The program objective questions were about the overarching project objective. Some requests were administrative (*Is NewMethod subsidized?*) and a request to add the user to the official WhatsApp group. The NGO worker may have needed an actionable step for these categories of questions.

CHATBOT USAGE: COMMUNITY CONTRIBUTIONS

The teachers also shared 182 stories and jokes during the year. The majority of these were shared during the teacher and advisor training. During training, teachers shared anecdotes about the training sessions and personal stories about teaching. The content shared positive experiences during the training and positive experiences during teaching. Teachers expressed the sense of community and positive emotions that they experienced as they were role-playing as students and teachers.

> I was the facilitator during *NewMethod* training, and my very old director was a student. I questioned him by calling him my little SIRI during my performance. It was funny but very enriching. - S219

Teachers also shared personal stories related to their prior classes. These stories centered around their struggling students and with whom the teachers had a personal connection in the past.

> Once in the afternoon, a student returned with a tight face; I asked him what he had. He answers Madame, I haven't eaten since morning. So I offered him bread to eat. Since then, I have been nicknamed Maman Cantine. - S230

After the training, teachers shared positive stories of behavior change from the program. These stories reflected how students become more attentive, punctual, and collaborative as an effect of the training activities.

> A student in my class remained away from the group, especially when his friends were in a working group. After we started the *NewMethod*, this child transformed and participated in activities a lot. - S246

7.5.5 Qualitative data

This section covers three high-level themes from our qualitative data. The first theme introduces teachers' contextual and practical challenges due to the *NewMethod* program. The second theme describes the opportunities and challenges for technology adoption. The last section discusses the role of the chatbot and the pedagogical program in teachers' career aspirations.

CHALLENGES AND CONTEXT

Contextual and Practical Challenges Affected *NewMethod* Implementation

Teachers mentioned the stark disconnect between the theoretical concepts taught at training and implementing *NewMethod* in their schools. During training, teachers practiced the activities in urban classrooms with good infrastructure and ample support from organizers. However, teachers implemented *NewMethod* in rural schools, which lacked the equipment to implement *NewMethod*. Teachers were asked to implement *NewMethod* activities on the floor, so all the classroom furniture had to be moved to the corners of the classroom before the sessions (and back to their original locations after *NewMethod*). Teachers mentioned that moving the benches was disruptive, as moving them before and after the *NewMethod* sessions took considerable time. Teachers also said that implementing *NewMethod* activities outside was hard due to the weather and ground conditions. Thus, these practical and context-specific challenges required support beyond the training sessions.

Teachers mentioned that the two philosophies of teaching, i.e., traditional teaching and *NewMethod*, had conflicting goals. Traditional teaching focuses on the country curriculum, requiring teachers to finish the curriculum for the grade before the academic school year. While *NewMethod* focused on foundational learning, *NewMethod* required teachers to support students' progress in basic math and French. The conflict in philosophy and practical challenges overloaded teachers and impacted teachers' overall well-being. Although teachers valued the benefits of *NewMethod* for students, they needed additional motivation to implement *NewMethod*.

> *NewMethod* has not lightened our workload, but the *NewMethod* is more beneficial to the children. After all, children are the most important part of our job. Otherwise, if it is about us teachers, these are two slightly different methodologies. Classical education has its methods, and the *NewMethod* has separate methods. The two methods compete for teachers' well-being and improving children's performance. - **T372 (community)**

Teachers were affected by the lack of resources and additional administrative responsibilities, which affected the quality of implementation. Teachers mentioned that official *NewMethod* documents provided in training took time to reach the rural areas. The lack of appropriate documents meant teachers could implement a subset of *NewMethod* activities, or students had to share material. Additionally, teachers in rural areas had many students(60-90 per class) with lower literacy levels, leading to larger *NewMethod* classes for lower levels. Large classes often needed to be

conducted outside classrooms where the lack of infrastructure intensified the quality of implementation.

Teachers also mentioned that administrative responsibilities and holidays would disrupt their *NewMethod* classes. Particularly, administrative meetings on Friday would disrupt the school's weekly *NewMethod* meetings (or session plans). Teachers said the session plan time was the only slot in their schedule to collectively solve challenges related to *NewMethod*. Teachers explained that they could not discuss during the daily *NewMethod* implementation slots as these slots were reserved for *NewMethod* implementation. Therefore, missing session plan meetings due to administrative appointments made finding opportunities to discuss *NewMethod* issues. Teachers also mentioned that missing a day of *NewMethod* class due to holidays or administrative meetings put them behind schedule, leading them to revise their earlier lessons.

> When we make session plans, we may not often finish the *NewMethod* implementation in the week, and then some meetings have nothing to do with teaching. When there are days that you have not been able to do the *NewMethod* courses, we are obliged to revise *NewMethod* with our students, and we do it.[..] they (administrators) do not consider these meetings. **T35 (individual)**

Discussions with fellow teachers, administrators, and remote colleagues supported *NewMethod*.

Teachers mentioned weekly meetings were a critical professional development source for *NewMethod*. All *NewMethod* teachers from the school would meet on Friday and plan *NewMethod* activities for the following week. Teachers could learn from these meetings through discussions and receive constructive feedback on improving their *NewMethod* implementation. Outside the weekly meeting, teachers received professional support from advisors and trainer visits who observed their *NewMethod* activities provided feedback on teachers' implementation, and answered their questions. Beyond physical sessions, teachers had various digital tools (such as phone calls and WhatsApp) to connect with their collegial community to receive support remotely. Teachers would call their colleagues or advisors to seek help based on their availability.

WhatsApp provided informal and formal avenues to seek support on *NewMethod*. Teachers had organically created WhatsApp groups in their inspections, which helped them stay connected after the training. There was an official WhatsApp group for *NewMethod* for directors where they were required to post videos of teachers implementing an activity in their school. Group members would receive

feedback from the teaching community on their content. The groups helped create a sense of motivation and a sense of belonging.

> It's a group of all those who have done the training who are on WhatsApp with our superiors, so it happens when there is a small problem and you ask several people to answer you. For example, we were asked to post images and videos of our *NewMethod* activities to check if we were doing the activities or if what we were doing was right or wrong. So when we share, they will criticize and show you how to conduct this activity, and automatically, you will receive feedback - **D422 (community)**

Benefits to children were a strong motivator for implementing *NewMethod*.

Teachers mentioned that superiors motivated them of *NewMethod*'s important role in improving the children's foundational literacy and numeracy. During their visits, advisors remind teachers about the significance of *NewMethod* in improving foundational education not just in their school but in all of Côte d'Ivoire. Teachers acknowledged the low foundational skills in Ivorian children were frustrating when fifth and sixth-grade students struggled to read simple words or numbers. Teachers felt they could not support struggling students as the traditional curriculum was fast-paced and focused on advanced topics, forcing teachers to leave weaker students behind. Therefore, teachers appreciated the focus of *NewMethod* on foundational skills. Teachers could observe the positive changes in the students after a short application period, which helped them stay motivated to implement *NewMethod*.

> When something is positive, there is no problem because our children don't know how to read and calculate, and *NewMethod* aims to correct this. So suddenly, it lightened some of our work tasks. Today, in my class in CE2 and even in CM2, some students need to learn how to count from 0 to 9. *NewMethod* only focuses on reading, calculations, and numbers, and there is an improvement (in those students).- **T372 (community)**

CHATBOT ADOPTION

Teachers used the chatbot to ask questions, access documents, and prepare lesson plans for *NewMethod*.

Teachers used the chatbot to ask specific queries about the teacher training program when they faced challenging situations. Teachers would ask questions related to

math, French, and ASER (evaluation) activities. Teachers found both automated and human responses to be helpful. Teachers appreciated the speed of automatic responses.

> I like the quick responses. When you ask questions, the chatbot automatically answers you, which implies that the answers are stored in the computer. - **T35 (individual)**

Teachers also mentioned that they were willing to wait for human answers when they faced difficulties while implementing *NewMethod*. They mentioned that the chatbot was a resource to resolve challenges while implementing the *NewMethod* program.

> We ask questions to DIA to ask for help on the *NewMethod*. DIA tells us to wait when it cannot give us results immediately. DIA guides us on how to do *NewMethod*. So, when we have difficulties with *NewMethod*, we ask DIA, and DIA answers us.**- T44 (community)**

The chatbot also provided opportunities to download the documents offline so teachers could continue learning about *NewMethod* when they didn't have access to the internet. Teachers often traveled during weekends and holidays to their families in remote areas without internet infrastructure. Offline access to Math and French training manuals helped the teachers continue working on their professional development when they didn't have access to the internet. Teachers used these manuals to prepare their lesson plans for implementing *NewMethod*.

> I downloaded the *NewMethod* manuals via DIA since my documents remain here (on the phone) when I go to my family (in rural areas), so via DIA, I have access to French and math documents, - **T372 (community)**

> Whenever I have to make my session plan, my *NewMethod* documents are often not with me because I usually go on a trip. So, I use DIA when I make my session plan. **T35 (individual)**

Teachers mentioned they used the chatbot during weekly meetings to plan their activities for the following week. Teachers met with their colleagues at the end of the week to discuss their work on *NewMethod* and brainstormed a lesson plan (session plan) for the following week. Teachers mentioned that they would often have challenges as they prepare for the week, which would be a typical use case for asking questions to the chatbot. Directors who supervised these meetings mentioned that they observed teachers using the chatbot when they had questions from these meetings.

> "Yes, but I can't say the number of times since I follow the activities and the session plan because teachers are the ones who write the session plan, and if there are questions, they ask and go to the app for answers. And at the end of the week, we work together and use the documents to see a bit of the session plan, so the facilitators use this application a bit." **- D422 (community)**

Community support allowed teachers to learn from and support fellow teachers digitally. Teachers mentioned that they would often visit the chatbot for stories that they found resourceful. Teachers also noted that these stories on the chatbot were resourceful as they inspired them to implement the program. Additionally, the stories also helped implement French activities. The *NewMethod* French activity started with "informal dialogue" sessions where teachers should have unstructured lightweight conversations to improve French comprehension. Teachers found creating new content for informal dialogue sessions challenging because the typical Ivorian pedagogy relied on structure and formal conversions. The chatbot stories were very useful in developing material; the stories helped create examples for informal dialogue.

> Yes, especially the anecdotes some colleagues share, which are often funny. In *NewMethod*, there is an informal dialogue (which involves storytelling). Therefore, we can refer to colleagues' anecdotes and inspire ourselves to tell stories to the children. These little stories and anecdotes are important because you can draw inspiration from them to move forward. **- T372 (community)**

Active users shared their personal stories with other community members. Teachers shared stories about how *NewMethod* helped improve student participation and attendance. Teachers also shared humorous content (jokes) to lighten the mood about *NewMethod* activities. Participants in the community condition could also answer questions from community members. Moderators could see the responses from the dashboard and approve the messages. The conversational agent sent an automated approval message to the submitter when moderators approved teachers' submissions. Teachers appreciated it when they received feedback from the conversational agent for their responses. Specifically, a teacher mentioned how they answered a difficult question to balance a large class.

> Yes, one of my colleagues has shared his question (on the chatbot) about handling 90 students. I told him to split his class into three or two groups in an activity and request that they work with a group independently. And DIA approved the response - **T44 (community)**

Multimedia on the Facebook page helped motivate and inspire teachers.

Teachers mentioned that the multimedia on the Facebook page was a valuable resource to support *NewMethod* implementation. Teachers could relearn their knowledge of the best practices for the program by looking at the pictures to observe their colleagues. Specifically, teachers couldn't obtain specific topics from the *NewMethod* manual when they needed support. For example, implementing ASER tests was not shown in the manual, and teachers could only gain this information during the first few days of teacher training. A teacher mentioned learning from the page was helpful because he was late on the training day when they taught the ASER tests.

> I was absent when they showed us how to do the ASER test because I came late. So, I used images on the Facebook page to help me implement the baseline ASER test. I saw the seating arrangement on the bench with the students. I also noticed that we should not keep documents around the table. These images enabled me to implement it myself. **- T35 (individual)**

Teachers drew inspiration from the multimedia to implement each activity differently. The NGO workers mentioned that implementing variations of *NewMethod* activities was essential to engage the children and improve their learning. However, teachers were implementing the training method for the first time, so they weren't clear about the variations boundaries. The multimedia on the page served as an example for teachers to adapt their implementation.

> The *NewMethod* Facebook page is an exchange platform; you must recognize that. There are activities and games that colleagues present. I saw a lady dancing with her children anyway it's interesting. She initiated, and afterward, we noticed that everyone could initiate things so that the children took an interest in the activity. **- D523 (community)**

The Facebook page regularly shared images from different parts of the country. Each post included school names, regions, and the activity. This information was obtained from ideas shared by teachers on the chatbot or WhatsApp groups. These posts helped teachers observe that training activities were being implemented at schools in different parts of the country. Teachers mentioned that they were motivated to conduct *NewMethod* in their schools.

> On this page of *NewMethod*, we saw that teachers had published sessions they had conducted in *NewMethod*. We saw everything done on the other side of REGION 1 and REGION 2. Seeing this motivated us to carry out our *NewMethod* sessions. **- T228 (individual)**

Technology adoption was affected by poor internet access and digital literacy.

Teachers living in remote rural towns couldn't access the internet network due to a lack of cell tower infrastructure. The inability to connect to the internet affected their chatbot adoption; teachers needed to travel to cities to access the chatbot. Some teachers requested that they be given access to the internet to use the chatbot regularly.

> It (chatbot) can help us, provided we can always connect to DIA. As we are in the village, we do not have an internet connection frequently here. So we can use DIA only when we travel away from our village - **D523 (community)**

Teachers also had device issues that negatively affected chatbot usage. Teachers in the context had outdated Android devices and old versions of applications. Outdated devices and older versions of applications made for a poor user experience when using social media. Most teachers didn't have the latest version of Facebook Messenger because there was no WiFi access. Thus, the applications (including Facebook Messenger) were never updated; therefore, teachers could not access the latest features required to improve user experience. Additionally, the devices often had physical limitations such as scratches or defects affecting phone usage. Although such devices could be used for basic utility for taking phone calls, it was hard to use advanced applications like social media. However, a few teachers mentioned sharing devices with their colleagues to access the chatbot.

> I had a problem with my phone screen while we were training. Even during the training, we had to answer questionnaires. So, I used it (DIA) from my colleague's phone. **- T228 (individual)**

Teachers also mentioned that they were still learning to use the advanced features of smartphones. Although teachers found value in learning to use smartphone features, they acknowledged that the initial stages were challenging and slow. However, they also believed their interest in learning this technology motivated them to surpass these limitations.

> It is normal to have a deficiency when accessing or learning a new approach. This deficiency can be corrected quickly if you take an interest in it quickly, which is what has been (with the chatbot). - **T184 (community)**

Technology adoption was reduced by offline access and WhatsApp groups.

Teachers mentioned that offline access to documents reduced their utility for DIA. Teachers could access PDF versions of the manual with detailed information about

the training program. Some teachers felt the manual had most of the information for *NewMethod*, so they found less utility in accessing the chatbot. Paradoxically, teachers mentioned that they found it hard to get relevant information from WhatsApp groups when needed because there were too many messages in the groups. Specifically, we observed that teachers found it challenging to find the manual as the message with the manual would be shadowed by the plethora of messages shared by multiple participants. We observed such responses in the control condition, which did not have stories. Furthermore, teachers thought they needed to overcome additional barriers to internet access and devices to access this information.

> Not everyone goes there (DIA) because they think it wastes time. After all, they already have the documents, so they refer to them if they need any information. So, if there were other information that has nothing to do with the manual on DIA, that would motivate people to use it. Also, all teachers don't have an internet connection or a smartphone. -**T35 (individual)**

Teachers also had access to colleagues on official and unofficial WhatsApp groups to seek help with *NewMethod*. Teachers mentioned that they were connected to other teachers and administrators from their inspectorate through these groups. Teachers shared multimedia, received critiques, and could ask their peers and administrators questions. Some of these groups were moderated by the administrators who would ensure that the content shared was relevant for *NewMethod*. Teachers also received notifications from posts that acted as reminders to use the technology. The notifications and presence of colleagues led some teachers to prioritize WhatsApp for support with *NewMethod*.

> In the context of *NewMethod*, WhatsApp is more interesting. In our IEP, we have our *NewMethod* groups; we communicate on these WhatsApp groups. We share information, send each other messages, and share new documents. **T184 (community)**

ASPIRATIONS

Technology literacy was important for career advancement.

Teachers wanted to progress in their careers to become advisors and mentioned that technology played a role. The career advancements required teachers to take additional responsibility outside their teaching, such as taking part-time courses or preparing for exam material. Teachers mentioned using digital tools to access

documents and take online courses to support themselves toward their future goals. Teachers noted that they used the internet to access content from the official websites, take online courses, and register for the exam on the official website. They also found value in searching for new resources online, i.e., they would go to European websites and download exam material.

> Yes, I am always connected to the internet. I go to educational platforms, i.e., the universities and large schools outside, to learn how things work there. - **T150**

DIA helped teachers gain technology literacy. Teachers mentioned that they struggled with digital literacy, and DIA deployment provided a pathway for improving their digital literacy. Teachers learned the basics of using their phones from DIA, which they mentioned were transferable for other applications and tasks for preparing for career advancements. For example, teachers noted that knowing how to download and read documents on their phones for the *NewMethod* manuals helped them download material about exam prep on their phones. Overall, they felt that DIA allowed them to improve their digital skills.

> Dia helps us use and not remain on the sidelines of computer tools. Today, the use of software and the Internet is needed everywhere. - **T184 (community)**

Social connections on WhatsApp helped motivate and study for exams. For exam preparation: Teachers needed to access a separate support network outside their teaching community; some teachers mentioned using social media to stay connected to study groups. These study groups often consisted of like-minded aspirants from different parts of the country preparing for career progression. Teachers mentioned they would also form study groups through individual connections (with family members or close friends). Teachers mentioned that these groups and connections provided them with content material that they would read in their free time. Teachers regularly received reminders from other members' activities, motivating them to prepare.

> Yes, a lot because. I'm in WhatsApp study groups, and almost every day, we learn many things from these groups. And in my free time, I try to practice, even though I don't know anyone in these groups. The *NewMethod* WhatsApp group could help me too because you can share what you don't know, and someone nearby may have the solution - **T228 (individual)**

***NewMethod* helped teachers learn the latest pedagogical skills**

Teachers mentioned that learning *NewMethod* helped them gain pedagogical skills for career advancement. Teachers mentioned that understanding and implementing *NewMethod* helped them gain practical skills in child development. Child development was an integral part of exam preparation, which they gained by implementing child-friendly activities of *NewMethod*. They could see personal and educational benefits in children's development. Teachers also mentioned that learning the latest trend in technology was integral to career advancement if they expected to mentor teachers in the future.

> Speaking of professional competitions, the typical subjects are based on the child. On how the child learns and on all the activities of the child. - **D422 (community)**

> Everything we learned from *NewMethod* allows us to progress and better assimilate what we teach the children. And it can help us understand and teach university courses. It updates what we have learned at CAFOP (teacher training) and in the field.- **T150 (community)**

7.6 Discussion and Future Work

H1 expected tech adoption to increase in the community condition, but the results were not statistically significant; Further examination of qualitative data gives hints to explain the phenomenon. Teachers expressed that DIA's features targeting resources reduced these features' utility over time. Teachers did not see the utility in asking questions that could be obtained from the manual *"They (teachers) think it's (DIA) a waste of time because they already have the NewMethod documents... .... So if there were other information that has nothing to do with the manual on DIA, that would lead everyone to look for it"*. This was feedback from a teacher in the control condition, indicating the redundancy of these features over time. The documents was solely targeted at user needs which Toyama mentioned would change over time [198]. In community support, teachers expressed that they valued stories that helped reinforce the importance of *NewMethod* for children. *NewMethod*'s ability to benefit low-performing students' foundational skills strongly motivated teachers to implement the program. The anecdotes from their fellow teachers helped them learn the program's importance through social proof [207] from their colleagues. *"Its little stories and anecdotes are important because you can draw inspiration from them to move forward."*

The qualitative data also shows competing technology platforms due to the presence of WhatsApp groups. Some teachers mentioned that the WhatsApp groups

made some of the features of DIA and the Facebook page redundant by providing similar solutions. Teachers could also use the WhatsApp group to ask questions instead of DIA. Although only one official group was set up by the NGO, teachers and administrators organically set up the rest of the groups. The self-motivation to set up the WhatsApp groups by the teacher community further solidifies the importance of community support in rural Ivorian teachers. Teachers could also seek multimedia on the Whatsapp group instead of the Facebook page. Teachers' positive feedback for multimedia's role in inspiring and providing learning opportunities from watching other teachers implement *NewMethod*. Additionally, the latest social media applications store multimedia offline, facilitating offline usage relevant to rural African contexts. In the initial version of the system, we considered a WhatsApp chatbot [30, 31], but teachers were worried about paying for data. We discovered that *free basics* was prevalent in Côte d'Ivoire, making Facebook more accessible to teachers. However, we believe WhatsApp's popularity motivated teachers to use the system to stay connected to their circles. Thus, future research can consider using multimedia and capitalizing agents on WhatsApp groups.

H2 expected improved motivation in the community condition, and we observed an increase in some sub-scales. For *agency combined*, i.e., teachers' professional agency in the community, there was a positive change over time for community users (difference-in-difference: 5.1 %). We also saw a greater difference in active community users (difference-in-difference: 8.4 %). The professional agency in the community scale asked questions about support (i.e., *I ask my colleagues for support when facing exhausting work situations. Our teacher community can care for our pupils together*). The increase in these differences indicates the benefit of vCOP for the community condition and provides evidence of a virtual community set up by the conversational agent. The vCOP version of the chatbot was designed to amplify [199] existing community interactions through digital interactions. Additionally, the stories helped reaffirm the benefits of the *NewMethod* program for the students and provided teachers to support each other through social proof. Specifically, in the vCOP version, teachers could request help from a colleague while waiting for an answer. These community-focused interactions may have helped reinforce strengths (asset [147]) in the context [33], leading to improved motivation.

We also observed an increase over time in *perceived colleague support* (difference-in-difference: 4.2 %); although the results were statistically insignificant, indicating hints of increased colleague support in the community condition. The *perceived colleague support* scales were meant to understand support from community members but the questions requested deeper connections to community members (*There is a colleague with whom I can share my joys and sorrows.*). We observe greater differences in active users with a marginally significant effect (7.4 %,p=0.2), hinting

at the positive change over time in the community condition towards colleague support.

However, we observed a negative change in self-efficacy for teaching in the community condition over time compared to the control, although the results weren't significant (-1.6 %, p=0.316). Prior work has shown that teacher self-efficacy drops when there is more burnout in the context of novel teaching practices [58]. From qualitative data, we learned that the *NewMethod* program and traditional teaching were conflicting from a teacher'perspective, *NewMethod* leading them to have an additional workload. For example, teachers mentioned that *NewMethod* disrupted their classroom activities as it required time to prepare for *NewMethod*. Thus, the conflict of *NewMethod* between traditional teaching and additional workload may have increased burnout, reducing self-efficacy over time.

H3 expected an increase in pedagogical knowledge in the community condition, and we observed a positive change only on one component for active users. Further examination of log data does not give us conclusive evidence. The knowledge questionnaire tested teachers on the theoretical knowledge of *NewMethod* (Knowledge question: *During the 'jump on numbers' activity, how likely is the student who jumps on numbers to find the correct number said by the other student?*). The French and Math sections were theory-based, and the ASER and mentoring sections contained a mix of practical and theoretical knowledge. However, the questions log shows that teachers used the conversational agent to ask practical questions about *NewMethod* (conversational agent question: *How to conduct the activity named jump on letters?*). Teachers' need for practical support can be explained by qualitative data where teachers said they referred to the chatbot specifically when they needed help *NewMethod* implementation. Therefore, the discrepancy between the theoretical questionnaire and the practical questions on the chatbot may hint at the lack of statistical significance.

Additionally, teachers mentioned using the chatbot offline through the offline manuals. We also see increased self-reports of offline usage in the control condition. Therefore, teachers could have gained theoretical knowledge from the manuals and have done well in the pedagogical knowledge questions through the manuals without accessing the chatbot. Alternative access to knowledge may have affected the outcomes.

Our analysis looked at changes in pedagogical knowledge over time using a difference-in-difference approach, but we later observed a complicated relationship in the data where knowledge increased in the post-test but subsequently declined 7.8. We also noticed that teacher knowledge did not maximize (reached an average of 15.7 out of 20) immediately after the training. Therefore, a different test other

than difference-in-difference approach may be needed to unpack the relationship between pedagogical knowledge and change over time.

The aspiration scales we used did not have validity (Cronbach alpha 0.44), but **qualitative data reveals that the chatbot supported teachers' aspirations through digital literacy and improved knowledge of *NewMethod*.** Teachers expressed that digital literacy is important in their efforts toward career advancement. Digital literacy in using the internet, such as forming connections with other teachers on social media, downloading files from the internet, and searching for information, were some skills that were useful to teachers. The chatbot helped teachers learn some basic literacy skills to help them through technology training. Another indirect role of the chatbot was to help teachers learn about *NewMethod*. According to teachers, learning *NewMethod* could play a role in staying up to date with the current trends of teacher professional development. Although digital literacy and the latest *NewMethod* were important for teachers' career aspirations, they were small steps in their multi-year journey toward career advancement. Teachers mentioned the importance of additional skills such as taking courses, passing exams, and broadening their social networks. The aspirations scale aimed to understand teacher aspirations holistically, which may have been too broad for measuring a multiyear journey. Future work can scope the questions on specific components, such as agency in digital literacy, to derive quantitative measures for working on aspirations.

Table 7.8 shows that **DIA has potential for human-AI collaboration,** demonstrated by the chatbot's ability to answer questions. Over the academic year, the chatbot was able to answer 25% of the questions, while the NGO worker answered 80% of the questions. Since this was an experimental setup, the NGO worker re-answered questions even if the chatbot answered them. The chatbot used a static database populated from prior work in Study 3. Hence, it could answer only a few questions beyond a greeting. Future work can focus on building a dynamic database for that chatbot, i.e., a chatbot that learns from NGO workers every new answer. The dynamic version of the chatbot allows for further improving the scope of human-AI collaboration [211] by reducing the workload of the NGO worker.

7.6.1 Limitations

One of the main limitations of Study 4 was connecting participants across multiple datasets. I formed a participant database by combing the surveys from *NewMethod* pre and post-tests, leading to over 554 participants. However, despite having over 600 users in the chatbot, only 334 could be identified as study participants using their demographic information. The chatbot collected demographic information

from teachers as an initial survey where phone numbers and names were used to identify users. Still, teachers' input errors in phone numbers and names didn't allow me to connect them with an identifiable participant in the study. Some teachers had multiple phone numbers or shared phones with their colleagues, making connecting these teachers across different datasets difficult. Teachers entered their names partially or missed questions, making it hard to associate these partial names with identifiable participants in the study. These errors were observed in multiple datasets and reduced the ability to connect different datasets efficiently.

Another limitation was the brevity of technology training sessions due to budget constraints and training resources. The Ministry of Education had a tight budget for training the teachers on *NewMethod*. The training occurred for a week, and teachers had to travel and stay in towns, i.e., inspectorates, during the training. The ministry supported the teachers by paying them a daily stipend, which constrained the number of training days. The per-day cost for every teacher restricted the total days that could be funded, leading the ministry to have a very intense training plan. The intense training plan could accommodate short technology training for only an hour in 2-3 sessions. The fast technology training sessions diminished the technology training quality as teachers had lower digital literacy.

Additionally, a low budget led to more field sites for training. Teachers were trained in 20 field sites to reduce their travel costs, which had to be covered by the ministry. Therefore, the five technology training teams (10 technology trainers) had to travel to multiple field sites over the week. The field sites were located far from each other, leading the technology team to travel for 2-3 hours to reach a field site. These travel constraints limited the total training sessions for every site, and teachers face value with the technology trainers. The lack of face value with technology trainers didn't allow teachers to ask follow-up questions and clarifications about the technology. Although the advisors, i.e., teacher trainers, were trained in the chatbot, they couldn't lead the sessions independently. Future work can find ways to accommodate longer technology training sessions and seek support from teacher trainers to assist technology training.

Another major issue with the system was the Facebook regulations on interacting with users and timely answers. Facebook limited agent-initiated interactions to a 24-hour window after the user's message to restrict spam messages through chatbots. This 24-hour limitation meant users could not be sent reminder messages or notifications beyond a day. Prior work [106] had shown that notifications are integral to reminding users to use the system. We also observed this in our qualitative data, where teachers mentioned that the WhatsApp group notifications prompted them to keep using the WhatsApp groups. The 24-hour limitation also restricted the timeframe for feedback to questions from the NGO worker. If the NGO worker could

not get to the questions in a day, then the teachers would not be able to receive the answers. For example, the NGO worker could not answer questions when traveling or on weekends. This limitation reduced the user experience of asking questions to the chatbot. To work around this issue, I sent SMS reminders to use the chatbot and notifications when the NGO worker answered questions. However, not all teachers entered their phone numbers correctly into the chatbot. Future work can consider applying for additional Facebook permissions that allow seven days of interaction for the Human (NGO worker) interacting with the agent.

7.7 Conclusion

This study makes a case for a virtual community of practice and conversational agents in low infrastructure settings. We conducted a longitudinal quasi-experiment with 313 teachers with two versions of the chatbot for community and individual support for a teacher training program in rural Côte d'Ivoire. The study aimed to understand the two conditions' impact on motivation, knowledge, and technology adoption. We hypothesized that there would be increased motivation, knowledge, and technology adoption. My analysis showed that community condition (1) improved motivation for some questionnaires, i.e., in agency in the community, and reduced burnout over time. Active chatbot users showed increased agency in the community and decreased burnout over time. Our qualitative data showed that the community condition allowed teachers to learn from and support each other using the chatbot. Teachers valued supporting children. The community condition saw reduced burnout and personal accomplishment, which was not significant. (2) improved pedagogical knowledge. An increased pedagogical knowledge in a category (ASER) was seen among active users of the conversational agent. Teachers also asked questions about French and ASER categories on the chatbot, indicating the chatbot's positive role in improving pedagogical knowledge. Teachers' offline access to pedagogical resources may have affected the low levels of change in the pedagogical knowledge (3) increase in technology usage. The community condition showed an increase in average technology adoption, but the results were not significant. Qualitative data suggests that offline utility, lower access, and the presence of other tools negatively affected technology adoption. Teachers mentioned they valued the stories, which motivated them to implement *NewMethod*. Finally, the chatbot improved digital literacy, an integral step for teacher aspirations. This study demonstrates the benefits of a virtual community of practice and conversational agent designs to support teacher professional development. Lastly, our work provides recommendations for measuring the impact of aspirations for future work.

CONTRIBUTIONS 8

A Case for Virtual Communities of Practice and Chatbots in Low-Infrastructure Settings. During the thesis period, Virtual Communities of Practice(VCOPs) [149]on social media were an emerging research area [203, 204, 205, 135]., but the participation of teachers from rural areas and content moderation was challenging were open problems [132]. Chatbots presented a promising opportunity to address these challenges [74, 167, 197], although chatbot research in rural African settings was a relatively new concept, and their potential impact was uncertain. To address these gaps in the literature, I undertook a series of iterative studies using the Design-Based Research approach [18, 52], allowing me to design features in a chatbot that support a virtual community of teachers. The chatbot designs showcased initial indications of their effectiveness in moderating interactions among the community of teachers with little effort from the NGO worker. My findings revealed innovative engagement methods in offline activities and rural teachers' intermittent utilization of technology. Finally, I devised and implemented a quasi-experiment to highlight the benefits of the virtual community of practice. This was done by conducting a long-term study with 334 teachers, showing how the vCOP idea helps in real situations. On a practical level, I have extended the theory of aspirations to designing technology for rural Ivorian teachers. Finally, my work has provided implications for policymakers to support rural teachers virtually.

Design: I conducted a series of iterative studies using Design-Based Research [18, 52] to create features for the chatbot to facilitate a virtual community of practice for rural teachers. While chatbots were promising for encouraging participation [167] and content moderation [197] in Western settings [74], their application hadn't been explored in rural African contexts. Therefore, prior work suggested employing qualitative methods and pilot deployments to transfer research to the new contexts [220, 127, 93]. I conducted qualitative studies and pilots to design a conversational agent for Ivorian contexts. I designed a conversational agent to aid a virtual practice community for teachers implementing a new professional development program. This conversational agent enabled teachers to share stories and engage in discussions to motivate each other within the community. The conversational agent's designs were inspired by teachers' peer support, a strength observed in the context. I expanded upon the concept of asset-based design by creating designs that leveraged the existing strengths and assets within the teacher

community. My work has contributed to the discussions surrounding virtual communities of practice [132] and chatbots [95, 94] for teachers in rural areas on social media platforms. My research findings can be applied to virtual communities in diverse contexts and fields, such as aiding community health workers in India [91] or care workers in the United States [156].

Participation: My findings revealed new ways rural Ivorian teachers engage offline and use technology intermittently. A noticeable gap in virtual communities of practice for teachers was that rural teachers faced challenges participating in real-time discussions on WhatsApp due to limited connectivity and access [132, 75, 81]. As per findings in other contexts [204, 87, 128, 155], understanding teacher participation is integral to teachers' professional growth. Therefore, I collected qualitative and quantitative data to understand teachers' participation. I identified obstacles to adopting technology, particularly concerning smartphone availability and internet connectivity among rural teachers. Nonetheless, these educators managed the situation by traveling to urban areas or commuting regularly to ensure better technology access. This approach allowed them to engage with the technology intermittently, i.e., once a week, to participate in virtual communities asynchronously. Even during periods without network access, teachers remained involved in virtual communities through offline activities, such as utilizing the *NewMethod* manual to prepare for their classes. Offline and intermittent connectivity patterns offer valuable insights for designing strategies to engage teachers in virtual communities. For instance, leveraging technology use during available periods, like using online forms and encouraging offline interactions [101], could enhance professional development opportunities.

Content Moderation: My designs have offered initial evidence of chatbots to support content moderation for virtual communities of rural teachers. One notable challenge in virtual communities is the necessity for moderation [132], particularly as these systems involve teachers with low digital literacy. In the specific context of Ivorian language teachers, content moderation posed difficulties due to the scarcity of moderation tools and the teachers' limited digital literacy. To bridge this gap, I conceived a humbot [74, 31], a system where human operators and artificial intelligence collaborate, particularly suited for constrained data availability for the chatbot to function independently. In this system, teachers could pose questions to the chatbot, and the AI component could assist them with basic inquiries and greetings. The NGO worker could then prioritize the questions based on relevance, even opting not to respond to more challenging queries. The chatbot also allowed teachers to access pre-approved stories moderated by the NGO worker, allowing for asynchronous engagement. The NGO worker effectively managed around 400 users, dedicating approximately an hour during peak usage times. For a future study, I incorporated a dynamic database for a subsequent study, enabling the chat-

bot to learn from each interaction. The chatbot responses progressively expanded, influenced by the NGO worker's input, growing from 15% in the initial year to 30% in the subsequent year. My research contributes to the discourse on human-AI collaboration [211], particularly toward using chatbots to enhance content moderation with passive moderator support for teacher communities in low infrastructure settings.

Evaluating Impact: I ran an experiment to assess the impact of the virtual community of practice by conducting a longitudinal study involving 313 teachers. While previous research has illustrated the qualitative advantages of virtual communities for teachers in low-infrastructure settings [132], the impact and long-term benefits are still unknown. Specifically, the effects on teachers' motivation, pedagogical knowledge, and technology adoption remain unclear. To address this gap, I designed a quasi-experiment (Study 4) involving two chatbot versions implemented in different regions withinCôte d'Ivoire. Teachers were granted access to a virtual community of practice in one region, while in the other, they had access to a traditional agent. I adapted existing questionnaires for teachers on motivation to teachers in the Ivorian context and validated them. I adapted and validated scales for perceived social support, agency within the community, burnout, and self-efficacy. The NGO shared the questionnaire for pedagogical knowledge. Subsequently, I demonstrated the intervention's effects through a longitudinal study. I trained over 400 teachers (313 were successfully identified) to utilize the chatbot at the commencement of the academic year and provided them with access throughout the year. I used a difference-in-differences [35, 69] approach to demonstrate the impact of virtual communities on teachers. In summary, my research contributes quantitative metrics supporting the positive effects of virtual communities on teachers' motivation and pedagogical knowledge. Future work could expand upon the utilization of these questionnaires and evaluate the impact of technology by including a control group that does not use technology.

Extending Aspirations Theory: In my research, I have extended the aspirations theory to encompass teachers in rural areas of Côte d'Ivoire. The aspirations theory [198] gained prominence [165, 101, 148, 26] during my dissertation in the Information and Communication Technology for Development (ICTD) literature. However, the theory had yet to be applied to designing technology to support teacher aspirations in Côte d'Ivoire. Therefore, I aimed to identify suitable strategies for creating culturally relevant technological interventions to assist teachers in their professional aspirations. In the initial chapter of my dissertation, I unearthed a crucial finding teachers' aspirations to progress as advisors conflicted with their current teaching responsibilities. The teachers faced the challenge of clearing demanding exams, necessitating extra preparation beyond their regular duties. This scenario limited their avenues for advancing their aspirations. However, I discov-

ered that teachers were role-playing as advisors to support their fellow educators within the community. This behavior presented a distinctive opportunity to utilize technology to motivate and aid teachers within this community. To implement this idea, I executed a pilot program in Chapter 3, wherein community support was facilitated through a conversational agent. In the subsequent Chapter 4, I gauged the efficacy of these design implementations using the theory of planned behavior. The evaluation showed that community support had a significant positive impact on teachers' perceived agency, although there were issues with the validity of the scales used for measurement. I hope that future researchers can take inspiration from my approach. A potential avenue for further exploration could be using the "hope index" [184] questionnaire to construct a metric for measuring aspirations. In summary, I have extended the conversations on aspirations [100, 165, 101, 148]; I expect my findings can help academic researchers and practitioners in ICTD space.

Lastly, I have deployed a chatbot system for the Ivorian government to support the pedagogical program. The system has inspired digital systems in the context, and the NGO has shown interest in using such technology in different parts of Africa. I discuss this contribution in detail in the subsequent section.

8.1 Implications for policymakers

What kinds of technology are culturally relevant for teacher professional development in rural Côte d'Ivoire?

Through my dissertation research, I have discovered the potential of digital tools in facilitating teacher professional development within rural schools in the Côte d'Ivoire. The project's emphasis on technology has motivated the NGO and ministry officials to explore digital tools for virtual teacher professional development. In previous chapters, I demonstrated the resourcefulness of conversational agents on platforms like WhatsApp and Facebook Messenger in supporting teachers' professional growth. Notably, Facebook is more accessible due to free basics, but WhatsApp is gaining popularity beyond the pandemic. The advantage of these conversational agents is that teachers can easily use them with minimal training. Furthermore, these tools can enhance teachers' motivation and knowledge levels, ultimately contributing to their professional development.

How to sustain the conversational agent and continue supporting teachers beyond the research phase?

This dissertation has demonstrated the benefits of using asset-based work [147, 221] towards improved technology adoption and sustainable design direction.

I also used teachers' limitations and opportunities with technology as assets for choosing the appropriate design, i.e., conversational agent. I used "community support" as an asset for inspiring the designs favorable to teachers in my final experiment. An asset-based approach has also provided opportunities to sustain the conversational agent beyond the research.

Sustaining the conversational agent beyond the research team requires software and content management resources. The software for the conversational agent incurs a cost of approximately $40 per month to maintain the cloud server hosting the chatbot. Additionally, occasional software maintenance is necessary to address system errors. Apart from the software aspect, regular content moderation by an NGO worker is essential. The conversational agent 's (AI) responses have expanded to learn from NGO workers' answers over two years, increasing from 15 in the first year to 30% in the second year. To continue supporting teachers effectively, the NGO worker must dedicate one hour daily to answering teachers' questions during peak seasons.

Teachers also require reminders to stay motivated and continue using the chatbot regularly. The NGO worker can post multimedia content on the Facebook page featuring teachers implementing the training, announcement, and pedagogical tips to inspire teacher communities. These Facebook posts can be scheduled in advance using a business management tool, optimizing the timing of periodic content, such as scheduling reminders on Fridays to prompt teachers to use the conversational agent during their weekly meetings.

Policymakers can explore various channels for reminders to improve system adoption. They can send automated SMS reminders via WhatsApp or official notifications. The study utilized the Twilio service to send automated messages to teachers, but future endeavors could consider collaborating with local partners like Africa's Talking to send reminders. Additionally, ministry officials could leverage official WhatsApp groups and other channels to encourage regular system usage.

To ensure long-term sustainability, policymakers should allocate resources to hire software developers to migrate the system to various platforms or countries. In the case of Côte d'Ivoire, policymakers should explore the option of migrating the system from Facebook Messenger to WhatsApp to align with alternative social media channels like WhatsApp groups. Investing in software development can expand the conversational agent to different countries and training programs through translation and adaptation.

8.2 Future Work

My research has identified opportunities for implementing virtual teacher training in rural areas of the Côte d'Ivoire. In future research, supporting teacher communities by incorporating mentors and integrating the conversational agent into teacher activities would be beneficial. This can be achieved by including mentors to guide and support teachers in utilizing technology effectively. Furthermore, integrating the conversational agent into routine teacher training activities, such as weekly goal setting, can enhance the overall training experience.

Designing for Mentor Support:

Our data indicate that administrators, including mentors and directors, have supported teachers' work using various technological tools like WhatsApp and phone calls. This support has been further amplified by increased technology adoption during the pandemic. Hence, future interventions can focus on creating pathways to enhance mentor-teacher support channels through digital tools to facilitate mentoring. Specifically, mentors can act as official technology champions, guiding teachers in adopting and utilizing technology effectively.

Collaborative Digital Goal Setting:

Another area of research to support technology adoption and training programs is the promotion of regular goal-setting behaviors. Our findings highlight the significance of regular goal setting in adapting the program to teachers' specific needs. However, external constraints have hindered teachers' ability to meet regularly for goal-setting sessions. To address this, future work can explore the use of technology to facilitate goal-setting behaviors through digital mediums. This intervention could involve providing teachers with goals and examples from teacher communities, enabling them to refine their session plans effectively.

Testing Impact of Technology:

This system assessed the impact of community support on a conversational agent, demonstrating that active technology users had higher agency and knowledge. Future experiments can evaluate the effect of technology through an A/B test. A future experiment could compare teachers who receive the technology and training methods with another group that only gets the training. A longitudinal quasi-experiment with multiple clusters at the inspectorate level could be conducted to examine the impact of technology. A quasi-experiment across inspectorates to avoid potential sample contamination, as teachers often interact with each other. Therefore, these interactions could lead to spillover effects.

Researchers should also be aware of the complex problem of user matching across large-scale data collection efforts. If WhatsApp usage is widespread, it could be considered a medium for associating users with their phone numbers. However, phone sharing and device loss may affect user matching reliability. Future work can further mitigate this problem by assigning unique identification numbers ("IDs") to participants before the experiment. These IDs can be provided during training; participants can use them as passwords when interacting with the conversational agent. In case of device loss, participants can be instructed to contact a designated phone number to revoke their previous number and obtain a new ID. Mitigating user matching will help researchers get a larger sample of users.

Finally, a good A/B test with technology would require good technology adoption. To improve technology adoption, future work could allocate more resources to integrate the system into the teacher training program. Good adoption can be achieved through training sessions, follow-ups, and reminders to ensure sustained engagement.

Content for Teacher Technology Training:

While teachers can use conversational agents, there are opportunities to enhance adoption by providing training to the teachers. Appendix B of the dissertation includes training materials utilized during the teacher training sessions. These training sessions consisted of interactive workshops conducted in 30-minute intervals, focusing on familiarizing teachers with the agent. The workshops used a straightforward instruction manual to explain the agent's objectives and various applications. Additionally, teachers received training within their community through interactive storytelling sessions, fostering a sense of belonging. Integrating technology training and refreshers within the teacher training agenda would greatly benefit educators. For example, dedicating just 30 minutes to targeted training resulted in over a 20-fold increase in feature usage.

Teacher refresher activities could be conducted using short surveys and think-aloud sessions. Teacher knowledge could be measured using periodic surveys. Think Aloud activities, which involve teachers utilizing different conversational agent features while vocalizing their thoughts, can be effective refresher exercises. For instance, a sample question could be: "How do you open the chatbot?" These refresher activities can be integrated into training implementation, enabling teachers to test and support their peers. For example, weekly planning meetings are an opportune time to administer the refresher activities.

Moreover, administrators such as pedagogical advisors, inspectors, and directors can provide technical support to teachers when they visit schools. Administrators

can encourage teachers to continue utilizing the chatbot and offer refresher guidance during their visits. Providing administrators with a checklist of conversational agent activities can help integrate technology training into their workflow effectively. Administrators can use the technology checklist when visiting every school to refresh teacher knowledge systematically.

Designing interventions specifically for teacher aspirations

Due to limitations and constraints, my dissertation could not directly align with teacher aspirations and provide comprehensive support to teachers. However, the intervention did contribute to developing a professional agency within their community, indirectly assisting them in aspirations in other areas, such as enhanced digital literacy and expanded networks. In future interventions, it would be beneficial to initiate projects that align with teacher aspirations and secure funding to design experiments to evaluate interventions that directly support and address these aspirations.

This dissertation has paved the way for assessing user agency in aspiration-based approaches. Although the scale I used had limited validity, future studies can build on my questions and develop comprehensive scales to measure user agency. The hope index [184] derived from positive psychology is an encouraging option from the existing literature. Future work could expand on combining my questions with the "hope index" to create a metric for aspirations. It would be valuable to validate this scale across different cultures and populations, ultimately creating a metric that can contribute to measuring social change in developmental contexts.

8.3 Reflection

I use this section to reflect on my research experience and propose recommendations for future projects. My research motivation was to design culturally responsive and sustainable technology support communities in low infrastructure settings. Culturally responsive technology includes cultural and linguistic elements to facilitate inclusive technology usage and adoption [43]. Sustainable technology is the intervention's ability to impact the community after the research [147]. An example of culturally responsive and sustainable technology is the Zimbabwe bush pump [43], a community-based pump invented, set up, owned, and maintained by rural communities. The pump achieves cultural responsiveness by including various local actors in setting and maintaining the pump. These actors' involvement is also integral to the adoption and impact of the intervention on the community beyond its setup. Over the following few paragraphs, I reflect on my experience designing a

conversational agent that included elements from the community and my goal to do good ICTD research.

Fieldwork and building solid partnerships with local actors were integral to the project. I traveled and kickstarted relationships during the early phase of the project. My advisor had another project in the country [119], so I could visit the country, participate in research [120, 122], and learn about the context in the early stages of my PhD. I built a rapport with local Ivorian researchers through these early research collaborations, who eventually played a crucial role in leading the local presence for research discussions with ministry officials and teachers in subsequent phases of my project. Traveling early to the context also helped me receive permits in-person and form relationships with senior officials at the ministry and NGO workers. I also sustained these relationships by having regular meetings and sharing intermediate deliverables to keep the partner engaged. The periodic interactions helped me stay updated with the research context and partner goals. These interactions also helped me seek support during critical phases of the research. For example, knowing the national coordinator for *NewMethod* allowed me to convince the ministry to include technology training in teacher training sessions. My key learning adds to the conversations in ICTD literature to forge strong relationships [174] and involve local researchers [9] to spend time in the context [80] in the early phases of the project.

I designed with and for multiple stakeholders [147, 80] and used open-source software [9] to create a culturally responsive design. Understanding the context and partners' needs helped design a custom-made artifact for all stakeholders. For example, all the stakeholders, i.e., NGO, ministry, and teachers, were concerned about the costs associated with technology projects and expected a low-cost system. Therefore, we prioritized designing a low-cost solution favorable to all stakeholders early on, which led us to social media-based intervention on Facebook. Another helpful resource was using open-source software. Open-source software like Rasa [138], FastAPI [60], and Ubuntu [54] helped us reduce the cost of software deployment. Open-source community support helped set up the system, and good documentation helped update the design for different experiments. Beyond costs, we noticed that the NGO workers were often overloaded due to a small team and frequent travel. Therefore, we picked humbots [74, 31] to reduce the burden on the moderator, i.e., the NGO worker who was already occupied to begin with. The principles of the Zimbabwean bush pump [43] can transfer to information technology and design for multiple stakeholders. My key learning adds to the prior literature on designing with communities and leveraging open source. Additionally, beyond open-source, prior work [9] recommends using simpler technology and frameworks that can easily be learned and managed by partners.

I learned that culture and stakeholders evolve, which affects action research, requiring researchers to adapt [9, 80]. Over the five years, we observed a change in personnel in the NGO that affected the organization's goals and the project's direction. The initial NGO workers left the organization, requiring me to rebuild my relationship with the new employees. Although having a strong connection with the initial team helped kickstart a new relationship, it needed many months to reorient the project when there was a personnel change. A change in junior NGO personnel would lead to a shift in design recommendations for the dashboard, leading to more work on software development. Alternatively, when senior management changed, it would often require us to reaffirm the project's benefits by presenting our previous findings and clarifying how the new senior personnel could support the project. Luckily, new hires were excited about technology and its impact on teachers, so there werent any significant issues; these changes just required more effort that wasnt accounted for. Key learning adds to the conversations of working with communities [9, 80], which requires flexibility when involving stakeholders and priorities.

Global events like the pandemic and policy changes affected partner priorities and research outcomes, which was challenging to adapt. Due to the COVID-19 pandemic, I could not travel to the country for two years, affecting research quality and partner interactions. I had to hire a data collection agency and teach them the basic principles of HCI remotely. Although the data collection team worked professionally, some essential elements of research were lost due to translation and lack of in-person interactions. During the pandemic, the NGO switched its goals from using Facebook to WhatsApp groups as WhatsApp became more popular during COVID-19. Due to the lack of in-person visits, the research team learned about the WhatsApp groups much later during the study, and the intervention was on Facebook Messenger as it was a favorable medium for research. Lastly, although Facebook was a conducive medium for research in the initial stages of the project, this changed after policy rules limited interactions by APIs such as chatbots [154]. A key lesson learned is that long-term projects can evolve unexpectedly, but researchers and partners can have human conversations to manage expectations [9] and adapt to the changes. For example, the NGO requested we postpone the research by a year because of the pandemic, as they could not run the study in 2021. We were empathetic to the request, and I used the time to run another pilot study and build a relationship with the data collection agency, ultimately strengthening the final study.

As documented in the literature, sustaining the technology beyond the research period was a complex problem [147]. Although the technology was low cost, multiple challenges affected technology transfer. This project initially aimed to transfer technology to the NGO, but the number of personnel changes over the years made

it hard to discuss the project's future. After my five studies, the ministry and NGO are very happy with the project and are enthusiastic to continue using it. However, the ministry has its internal assessments and limited projects to prioritize its resources in the future. Although research leaders expect to facilitate technology transition beyond the project, it is still unclear if the ability to sustain technology is entirely up to the researchers. Beyond the specifics of the context, it is essential to be mindful of the community impact gap in academic research. As Poon phrases it: The infrastructures and incentives of the academic system are not aligned with creating sustainable community impact [1]. For example, In my case, I had incentives and checkpoints to do academic research at my university. However, I had fewer incentives and structures to transition and allow the community to take ownership of the technology. Beyond academic results, it is the community's (NGO, education ministry) decision to continue using technology [147, 80]. Thus, sustaining the technology itself may be an enormous expectation. This learning adds to the prior literature suggesting ICTD researchers [9] should manage expectation internally when attempting academic research and developmental outcomes.

Although sustaining technology impact is complex, unexpected positive effects on stakeholders provide ideas to broaden the concept of impact. Teachers found benefits in gaining technology literacy which was vital to their career aspirations. Teachers used the chatbot intervention to gain skills that helped them download content and navigate to relevant websites. For the NGO, the chatbot played a role in capacity building a new employee, i.e., answering questions helped onboarding a new employee. Answering teachers' questions on the chatbot helped NGO workers learn about the pedagogical strategies and gradually transition into their role as content experts. Additionally, interacting with teachers on the chatbot helped NGO workers build rapport with the rural teacher communities, which was an integral part of their job. Another positive benefit was ideas and inspiration. The NGO and ministry learned from our research presentations (which we regularly did) and planned for virtual teacher training in the next few years. The NGO was keen on using the chatbot in another country to support teachers. These phenomena express the need to broaden the definition of impact [80, 9, 174, 147] in community-based projects where impact can go beyond traditional success indicators.

I situated my research in established theories to allow transferability. One of the limitations of ICTD research is its specificity to the community [44], making it hard to transfer research ideas across projects or to general HCI [28]. I situated my research in existing theories to allow transferability to other communities in low-resource infrastructures. In my research, I used established theories like community of practice [213] familiar to the broader HCI community. COPs help me structure my findings and frame my contributions in virtual communities of practice [149], abstracting the specifics of the context, teaching method (*NewMethod*), and geogra-

phy. I also used theories trending in ICTD literature like asset-based design [221, 147, 67] and aspirations [198]. Using assets" helped derive technological designs to create a workable intervention that included the existing strengths of the teacher population. The theory of aspirations helped me situate my designs toward benefiting the user's teachers' long-term careers. However, I would consider using fewer theories to strengthen the contribution and clarify the narrative for future research. As a junior researcher, it was hard to stick to one theory as academic trends kept shifting periodically.

Lastly, I found support from a scientific community of like-minded people during my PhD. I volunteered and eventually led workshops for a scientific community called "HCI Across borders," or HCIxB [109]. HCIxB comprises of researchers who expand HCI work beyond conventional user-centered research. HCIxB aims to support early career researchers worldwide who may need access to the necessary resources and mentoring. Every year, I gathered researchers from all over the world to discuss various themes that challenge the traditional borders in HCI. Over the years, I helped organize workshops that focused on Global Solidarity in 2023 [34], discussed the shifting challenges in the pandemic in 2022 [32], reflected on design challenges stemming from decolonial thinking in 2021 [108] and discussed designing for UN's SDG goals 2020 [108]. Organizing the workshops helped me have exciting discussions, which helped me think critically about my research. For e.g., while learning about decoloniality [217, 219], I reflected that Human-AI guidelines [6] may not be ideal for my population, so I resolved to boldly use USSD menus that were favorable to my users but were against traditional designs. Although unrelated to research, having a like-minded group of community members helped shape my research trajectory.

To summarize, I reflected on my motivation and experience from my PhD to provide recommendations for future work. I was motivated to design culturally responsive work and sustainable technology for low infrastructure contexts. I built long-term relationships and engaged in fieldwork, which was integral during the critical phases of the projects. The long-term nature of the project also required adaptability as culture and stakeholders' goals evolved during the project. Working in changing contexts required expectation management about outcomes internally among the research team and externally with the partners. For outcomes beyond the research, sustaining technology after the research was complex, but the project had unexpected benefits for different stakeholders, giving room for a broader definition of impact. Lastly, situating my research in established theories allows transferability to other HCI contexts.

9 CONCLUSION

To improve educational outcomes, governments are investing in pedagogical programs that require well-trained teachers. However, implementing teacher training interventions in rural and isolated areas is difficult due to infrastructure and socio-cultural complexities. Technology has shown potential in supporting teacher training interventions, but there is limited understanding of its effectiveness in rural African contexts. Conversational agents like chatbots have provided personalized support to teachers in rural African contexts. However, considering socio-cultural nuances, there is a need to bridge the gap between AI research and low-infrastructure contexts. This dissertation uses a Design-based research approach through a series of studies to uncover the potential of chatbots to support teachers in low-infrastructure settings. I conducted initial studies (Study 1, Study 2, and Study 3) to find the feasibility and importance of community support, i.e., virtual community of practice. Therefore, this led me to my dissertation question: ***How does a conversational agent that supports a virtual community of practice (vCOP) impact teachers in low infrastructure settings?***. In Study 4, I evaluated the impact of vCOP in a conversational agent through a longitudinal, large-scale deployment.

Chapter 1 of the study focuses on incorporating technology in teacher professional development in low-resource contexts, particularly in rural areas of Côte d'Ivoire. Through a qualitative study involving 22 teachers, the chapter explores their aspirations, community support systems, and innovative approaches to professional development. The findings highlight the need to balance personal and community aspirations in program design and propose methods for measuring aspirations. The chapter also provides implications for designing effective teacher professional development programs that drive social change.

Chapter 2 consists of two parts. The first part involves deploying a chatbot "DIA" to support teacher training. The deployment of DIA gathers topic-specific questions and provides insights into teachers' mobile phone usage patterns in rural areas. The data revealed the limitations of needs-based approaches and the importance of sustaining teacher agency. The second part presents findings from a qualitative study with 30 teachers in rural Côte d'Ivoire, emphasizing the role of aspirations in shaping sustainable ecosystems for teacher development. Design ideas are proposed to operationalize aspirations, foster communities, and prioritize teacher agency.

Chapter 3 provides initial evidence supporting the use of participatory content features for community support through the chatbot. The chapter demonstrates that teachers effectively engage with the chatbot's community features, sharing information and answering questions about teaching and learning at the right level. Challenges such as offline access and limited network availability are identified, underscoring the importance of mentor support and expanding the chatbot's database to enhance its functionality based on teachers' questions.

Chapter 4 contributes to the open problem of whether to provide community support through virtual communities of practice. To address this, a longitudinal quasi-experiment was conducted with 400 teachers, comparing two conversational agent versionsone providing community support and the other offering individual supportin a teacher training program within rural Côte d'Ivoire. The goal was to measure motivation, knowledge, and technology adoption changes between the two conditions. Based on prior literature and a theory of change, it was hypothesized that the community condition would lead to increased motivation, knowledge, and technology adoption. The analysis revealed that the community condition showed (1) improved motivation, fostering positive changes for agency within the community. Qualitative data indicated that the community condition enabled teachers to learn from and support each other through the conversational agent. However, the community condition showed a decrease in burnout, but the results were not significant, potentially influenced by the additional workload on teachers from *NewMethod*. (2) improved pedagogical knowledge, with an increase in ASER category among active users of the conversational agent, indicating the conversational agent's positive role in improving pedagogical knowledge. (3) improved technology usage to some extent, with an increase in average technology adoption in the community condition, although the results were not statistically significant. Qualitative data suggested that factors such as offline utility, limited access, and the presence of other tools negatively affected technology adoption. Teachers in the community support group valued the stories on the chatbot, which motivated them to implement *NewMethod*. Lastly, technology played a role in enhancing digital literacy, a crucial step for fostering teacher aspirations.

My work makes a case for virtual Communities of Practice (vCOP) and chatbots in low-infrastructure settings. My dissertation adds to the HCI literature by providing insights into designing interventions, understanding rural teachers' participation, content moderation with a chatbot, and evaluating the impact of such systems. Policymakers can draw implications from this dissertation by utilizing culturally responsive technology that facilitates vCOP for teacher professional development. Lastly, the dissertation proposes future endeavors in devising scales to measure aspirations and designing interventions that align with teacher aspirations.

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Appendix

A

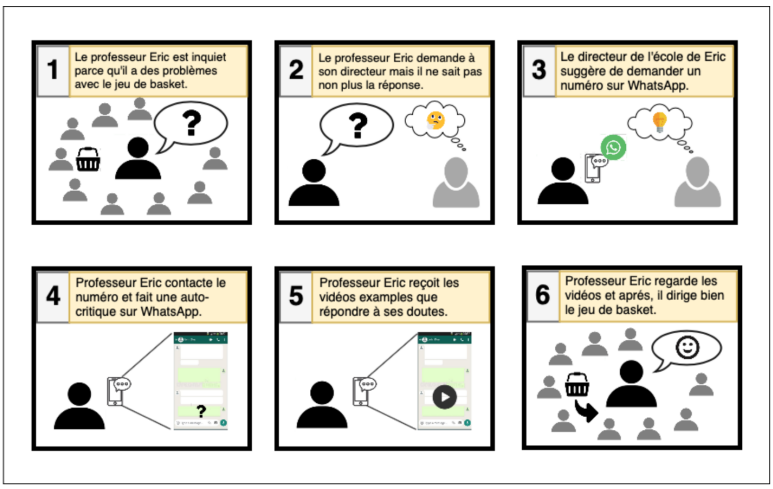

Fig. A.1.: Storyboard 1: Here, the chatbot is helping Teacher Eric with an activity to implement a pedagogical program.

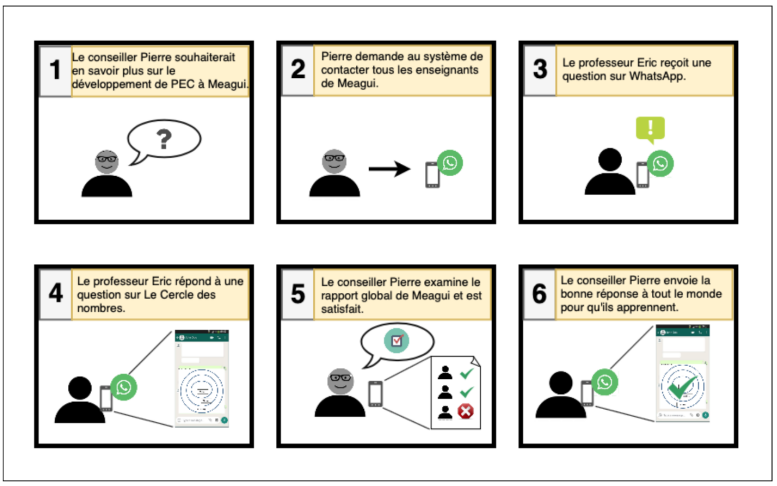

Fig. A.2.: Storyboard 2: Here, the chatbot supports an advisor to monitor the teachers in the region using a quiz.

Tab. A.1.: Table summarizing our code book from questions

Subject/Classroom Teaching 31 (28%)
Geography 11
History 6
Math 4
Ivorian Administration 4
Grammar 3
Science 2
Teaching method 1
***NewMethod* 25 (23%)**
NewMethod info 11
NewMethod implementation 11
NewMethod resource 3
Feedback 24 (22%)
Clarification 17
Greetings 5
Feedback 2
COVID 10 (9%)
Covid news 7
Covid treatment 1
Covid symptoms 1
Covid forward 1
Other 9 (8%)
Sport 5
News 4
Personal 6 (6%)
Business advice 4
Sexual Health 2
***NewMethod* logistics 4 (4%)**
NewMethod logistics 3
NewMethod implementation 1

Tab. A.2.: Shows the Cronbach alpha in the baseline data for the different questionnaires. The red indicates a low Cronbach alpha.

variable	Cronbach alpha
perceived social support	0.887
self efficacy	0.8
agency: transformative practice	0.844
agency: collective efficacy	0.889
agency: positive interdependence	0.883
agency: active help seeking	0.736
agency: proactive strategy	0.851
agency: combined	0.96
burnout: personal accomplishment	0.755
burnout: emotional exhaustion	0.623
burnout: depersonlization	0.231
burnout: combined	0.623
aspirations: socialnorms	0.074
aspirations: agency	0.373
aspirations: combined	0.446

E	F	K	N	O	P
Text	**Translated text**	**Week**	**Theme**	**Category**	**Code**
Quels sont les états membres de la CEDEAO	WHAT ARE THE ECOWAS Member States	1	Subject	Geography	Georgraphy factoid
l'Union Africaine comprend combien de pays	The African Union includes how many countries	1	Subject	Geography	Georgraphy factoid
À quel moment utilisé t-on voici où voilà ?	When it is used here are it?	1	Subject	Math	Math teaching
Conjuguer le verbe pleuvoir au présent simple de l'indicatif	Conjugate the verb rain to the present simple indicative	1	Subject	Grammar	Grammar question
Que signifie PEC	What does PEC mean	1	PEC	PEC	PEC info

Fig. A.3.: Analysis of questions for Study 2

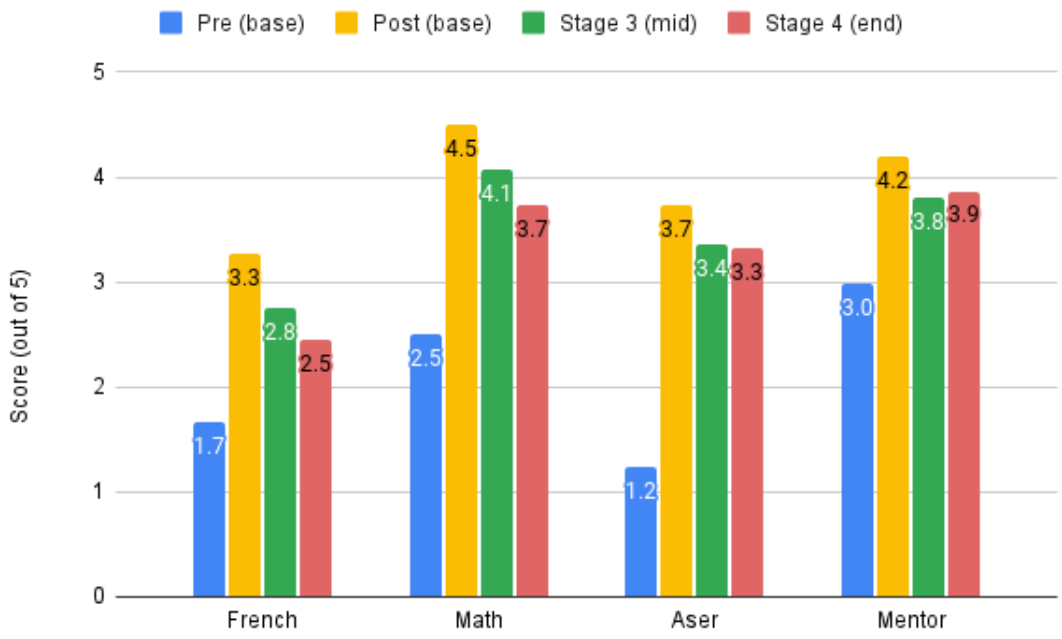

Fig. A.4.: Trend of questions for different components of Knowledge 7.5.3

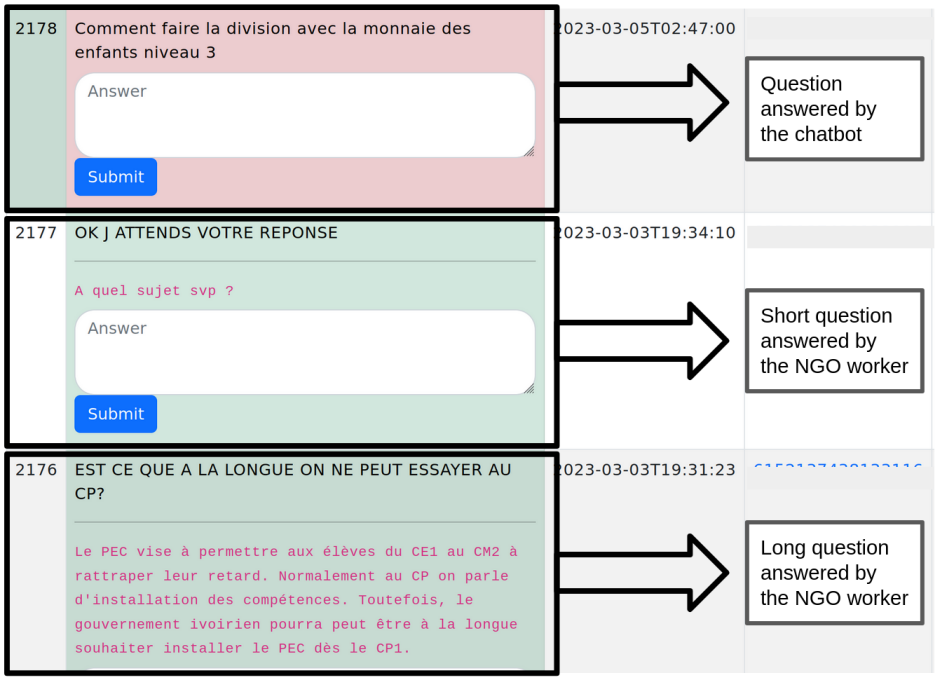

Fig. A.5.: The NGO workers dashboard with examples demonstrating automated and human answers

Tab. A.3.: Shows the differences in differences for questionnaires in motivation and knowledge. The table also includes variables that were not included in the final hypothesis testing.

MOTIVATION

	community condition (n=82)		control condition (n=61)		community vs control			(A1) active community vs control		
	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	did (%)	p value	q value
perceived social support	82.9	82.7	83.1	78.4	4.2 (-2.3,10.8)	0.2	0.276	7.4 (-0.9,15.8)	0.079	0.125
self efficacy	84.9	81.5	83.2	81.2	-1.6 (-4.8,1.6)	0.316	0.348	-0.8 (-4.3,2.8)	0.67	0.67
agency: transformative practice	86.9	89.6	88.7	87.7	4.2 (-1.9,10.2)	0.175	0.275	9.7 (2.2,17.2)	0.012	0.06
agency: collective efficacy	87.9	91.4	91	89.8	3.8 (-1.5,9.1)	0.157	0.275	5.4 (-1.8,12.6)	0.141	0.194
agency: positive interdependence	88.5	94.8	94.3	93.2	5.9 (0.6,11.2)	0.028	0.151	8.4 (0.4,16.4)	0.041	0.099
agency: active help seeking	86.3	91.8	90.5	91.6	5.5 (-0.7,11.8)	0.08	0.193	8.1 (-0.8,16.9)	0.073	0.125
agency: proactive strategy	86	92.7	91.5	89.4	6.9 (0.8,12.9)	0.026	0.151	10.9 (3.2,18.6)	0.006	0.06
agency: combined	87.2	91.9	91.1	90.1	5.1 (0.2,9.9)	0.041	0.151	8.4 (1.6,15.2)	0.016	0.06
burnout: personal accomplishment	95.7	95.6	93.2	96.4	-2.3 (-6.3,1.7)	0.251	0.307	-2.1 (-6.3,2.1)	0.313	0.344
burnout: emotional exhaustion	33.8	35.3	31.4	34.3	-3.4 (-7.3,0.5)	0.088	0.193	-4.6 (-9.0,-0.1)	0.045	0.099
burnout: depersonlization	23.3	21.5	22.2	21.4	2.7 (-1.3,6.6)	0.183	-	1.0 (-3.7,5.7)	0.675	-
burnout: combined	-27	-25.5	-27.7	-26.9	-1.9 (-6.5,2.7)	0.412	0.412	-3.2 (-8.2,1.8)	0.206	0.252
aspirations: socialnorms	49.3	49.7	52.2	48.2	2.5 (-1.8,6.7)	0.255	-	3.4 (-1.6,8.4)	0.183	-
aspirations: agency	79.2	78.6	76.5	76.7	-2.5 (-8.5,3.4)	0.395	-	-1.8 (-9.0,5.3)	0.61	-
aspirations: combined	74.1	74.1	74.8	72.1	0.4 (-4.3,5.2)	0.851	-	1.4 (-4.1,7.0)	0.602	-

ASPIRATIONS

	community condition (n=82)		control condition (n=61)		community vs control			(A1) active community vs control		
	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	did (%)	p value	q value
social norms: superior approval	85.2	80.7	81.9	80	-3.3 (-8.9,2.3)	0.249	0.332	-2.3 (-8.7,4.0)	0.466	0.622
social norms: successrate	52.8	58.4	64.1	54.9	10.2 (-0.7,21.0)	0.066	0.262	11.8 (-0.7,24.3)	0.065	0.258
agency: success confidence	78.7	76.5	74.3	74.5	-0.0 (-8.9,8.9)	0.997	0.997	-0.5 (-11.6,10.6)	0.933	0.933
agency: success self-reliance	79.8	80.8	78.7	78.9	-5.1 (-11.9,1.8)	0.144	0.287	-3.2 (-11.0,4.6)	0.416	0.622

KNOWLEDGE

	community condition (n=51)		control condition (n=40)		community vs control			(A2) all active vs inactive users		
	baseline (%)	endline (%)	baseline (%)	endline (%)	did (%)	p value	q value	did (%)	p value	q value
french	33.8	47.7	32.9	52.5	4.8 (-4.7,14.3)	0.319	0.946	-1.8 (-11.7,8.2)	0.724	0.772
math	47.3	75	46.2	75	-0.6 (-10.5,9.3)	0.899	0.946	1.5 (-8.8,11.8)	0.772	0.772
aser	27.7	67.7	26.2	68	-0.7 (-9.8,8.4)	0.88	0.946	9.9 (0.7,19.0)	0.035	0.176
mentor	55.8	75.8	57.6	80	-0.4 (-10.8,10.1)	0.946	0.946	1.8 (-9.4,13.0)	0.75	0.772
knowledge	41.2	66.5	40.7	68.9	0.8 (-4.9,6.4)	0.786	0.946	2.8 (-3.3,9.0)	0.361	0.772

did (%) indicates difference in differences in percentage with 95% confidence intervals.
p value <0.05 is considered significant, p value < 0.01 is considered marginally significant.
q value is the FDR corrected p value using Benjamini Hochberg correction.

Tab. A.4.: Baseline data categorized by questionnaires for the two conditions. This data was used for MOTIVATION([7.5.2]) analysis

Variable category	Question	Community mean	Control mean
Demography	inspectorate	11.5505618	8.349206349
Demography	class	1.505617978	1.507936508
Demography	gender	1.797752809	1.777777778
Demography	village_id	81.8988764	83.76190476
Demography	What class are you currently teaching at this school?	3.348314607	3.158730159
Demography	In what languages do you usually teach students?	1.02247191	1
Demography	How many years of teaching experience in total do you have?	9.606741573	11.17460317
Demography	How many years of teaching experience in this school do you have?	4.91011236	5.587301587
Demography	What is your age in years?	37.95505618	39.31746032
Demography	What is your grade in teaching?	2.528089888	2.682539683
Demography	What is your highest qualification	2.696629213	2.650793651
students_info	How many children were enrolled in your class at the beginning of the year ?	37.50561798	35.26984127
students_info	How many children do you currently have in your class?	35.62921348	32.17460317
students_info	How many children do you think will be able to finish the school year?	34.13483146	30.15873016
students_info	Are students used to arriving on time?	0.4831460674	0.6507936508
Teaching_practice	Have you been absent one day from school last week?	1.348314607	1.365079365
Teaching_practice	If you were absent from school on any day of thelast week, why?	1.202247191	1.333333333
Teaching_practice	In the last school year, how often does the headteacher observed your lessons?	7.224719101	6.111111111
Teaching_practice	In the last school year, how often did a counsellor observe your lessons?	7.97752809	8.126984127
Tech_access	What type of phone do you have?pea	1.280898876	1.333333333
Tech_access	Which mobile operator do you have on your smartphone?	0.3820224719	0.3492063492
Tech_access	How many years would you say you've been using smartphones?	6.06741573	5.857142857
Tech_access	If you have a smartphone, how much did you spend last week	1308.426966	1608.730159
Tech_access	How often do you buy a data pack on your smartphone?	2.471910112	2.333333333
Tech_access	How many days a week do you access the internet/social media?	2.685393258	2.920634921
Tech_access	Where do you have a telephone network to use the internet/media?	1.168539326	1.26984127
Tech_access	How often do you use SMS on your phone?	2.337078652	2.793650794
Tech_access	How often do you use CALLS on your phone?	1.202247191	1.476190476
Tech_access	How often do you use FACEBOOK on your phone?	3.168539326	3.365079365
Tech_access	How often do you use MESSENGER on your phone?	3.91011236	3.936507937
Tech_access	How often do you use WHATSAPP on your phone?	2.91011236	3.238095238
Tech_access	How often do you use GOOGLE SEARCH on your phone?	3.651685393	4.031746032
Tech_access	How often do you use the CAMERA on your phone?	4.056179775	4.111111111
Tech_access	Do you use Facebook Messenger?	0.6853932584	0.746031746
Tech_access	What color is your Facebook Messenger icon?	1.213483146	1.333333333
Tech_access	I'm ready to use Facebook Messenger to improve my pedagogical competences	1.741573034	2.047619048
Aspirations	Why did you choose to become a teacher?	0.7191011236	1.158730159
Aspirations	Was elementary school teaching your first career choice?	1.460674157	1.444444444
Aspirations	What job do you expect to have in five years?	3.02247191	3.238095238
Aspirations	Most important people approve my career?	1.696629213	1.793650794
Aspirations	Most teachers like me achieve their career goal in 5 years	2.662921348	2.301587302
Aspirations	Are you confident that you can achieve your career goal in 5 years?	1.808988764	2.047619048
Aspirations	Will you achieving your long-term career goal entirely	1.831460674	1.936507937
Self efficacy	I am convinced that I am able to successfully teach all my students	1.685393258	1.793650794
Self efficacy	I know I can maintain a positive relationship with students, even under stress	1.640449438	1.746031746
Self efficacy	When I make great efforts, I am able to reach even the students	1.719101124	1.80952381
Self efficacy	I am convinced that over time, I will continue to become able to respond my students needs	1.573033708	1.777777778
Self efficacy	Even if I am disturbed during teaching, I know how to keep calm	1.595505618	1.80952381
Self efficacy	I am confident in my ability to meet the needs of my students, even though I have a bad day	1.629213483	1.857142857
Self efficacy	If I try hard enough, I know I can exert a positive influence	1.640449438	1.793650794
Self efficacy	I am convinced that I can develop creative ways to face the education system challenges	1.853932584	1.80952381
Self efficacy	I know I can motivate my students to participate in new activities	1.617977528	1.746031746
Self efficacy	I know that I can carry out new teaching activities in my	1.91011236	1.904761905
Burnout	I feel emotionally drained from my work.	3.483146067	3.507936508
Burnout	I feel used up at the end of the workday.	4.382022472	3.968253968
Burnout	I feel fatigued when I get up in the morning and have to face another day on the job.	2.584269663	2.047619048
Burnout	I can easily understand how my school children feel about things.	6.146067416	5.492063492
Burnout	I feel I treat some school children as if they were impersonal objects	1.146067416	1.126984127
Burnout	Working with people all day is really a strain on me.	1.280898876	1.142857143
Burnout	I deal very effectively with the problems of my school children.	6.359550562	6.285714286
Burnout	I feel burned out from my work.	2.95505618	2.682539683
Burnout	I feel I am positively influencing other peoples lives through my work.	5.550561798	5.26984127
Burnout	I have become more cold toward people since I took this job.	1.505617978	1.952380952
Burnout	I worry that this job is hardening me emotionally.	1.606741573	1.46031746
Burnout	I feel very energetic.	6.348314607	6.365079365
Burnout	I feel frustrated by my job.	1.123595506	1.396825397
Burnout	I feel I am working too hard on my job.	4.011235955	3.825396825
Burnout	I do not really care what happens to some school children.	1.966292135	1.53968254
Burnout	Working with people directly puts too much stress on me.	1.404494382	1.26984127
Burnout	I can easily create a relaxed atmosphere with my school children.	6.685393258	6.587301587
Burnout	I feel excited after working closely with my school children.	6.719101124	6.507936508
Burnout	I have accomplished many worthwhile things in this job.	6.258426966	5.571428571
Burnout	I feel like I am at the end of my rope.	1.876404494	1.476190476
Burnout	In my work, I deal with emotional problems very calmly.	6.516853933	6.095238095
Burnout	I feel students blame me for some of their problems.	2.651685393	2.26984127
Community Agency	Other teachers' ideas inspire me to advance my own teaching.	4.325842697	4.380952381
Community Agency	I'm willing to discuss my own work with my teacher colleagues.	4.516853933	4.634920635
Community Agency	The discussions in the teacher community inspire my work.	4.157303371	4.317460317
Community Agency	I'm able to utilize the feedback from teacher colleagues in developing my teaching.	4.370786517	4.412698413
Community Agency	We are able to deal with challenging school situations together.	4.516853933	4.714285714
Community Agency	Our teacher community is able to take care of our pupils together.	4.438202247	4.603174603
Community Agency	The common development work in our school has made it easier to carry out my own teaching.	4.224719101	4.142857143
Community Agency	In our teacher community we encourage each other to develop.	4.404494382	4.746031746
Community Agency	I'm able to utilize the critical feedback I get from the teacher community.	4.247191011	4.619047619
Community Agency	I encourage my teacher colleagues to collaborate.	4.584269663	4.793650794
Community Agency	I'm willing to act in order to advance the best of our entire teacher community.	4.449438202	4.73015873
Community Agency	I can discuss even the difficult subjects in my teacher community.	4.247191011	4.476190476
Community Agency	I'm not afraid to ask the other teachers for help.	4.382022472	4.571428571
Community Agency	I'm able to support the colleagues who feel strain in their work.	4.426966292	4.587301587
Community Agency	I ask my colleagues for support when facing exhausting work situations	4.191011236	4.476190476
Community Agency	I'm getting better and better in recognizing the situations in which I have succeeded as a teacher	4.280898876	4.666666667
Perceived social support from colleagues	There is a colleague who is around when I am in need.	4.235955056	4.349206349
Perceived social support from colleagues	There is a colleague with whom I can share my joys and sorrows.	4.337078652	4.26984127
Perceived social support from colleagues	There is a colleague in my life who cares about my feelings.	3.966292135	3.857142857
Perceived social support from colleagues	I have a colleague who is a real source of comfort to me.	4.033707865	4.174603175

Tab. A.5.: Questions used for KNOWLEDGE & SKILLS[7.5.3] analysis

Category	Question	Options
FRENCH	1. What activity should be conducted only by students in the "word and paragraph" level group?	Word card Correct the error Word chain The basket game I don't know
FRENCH	2. The reading of the "phonetic-syllabic table" begins with:	Reading the columns of consonants Reading the lines of vowels None of the two I don't know
FRENCH	3. The dictation must be conducted:	Every day every other day Once a week I don't know
FRENCH	4. The "basket game" activity can be traded individually:	True False I don't know
FRENCH	5. We can not conduct an activity of "paragraph reading" with children with beginner / letter levels	True False I don't know
MATH	6. Mathematics activities start with:	Operations Recognition of numbers by both I don't know
MATH	7. During the "subtraction with sticks" activity, if a packet is moved in the sticker column, it is converted into a sticks.	True False I don't know
MATH	8. During "Jumping on the numbers", the student who jumps on the number A, how many chances to find the correct number for the other student?	1 Chance 2 chances 3 chances I don't know
MATH	9. During "The circle of numbers", the pebbles to account after the launch are:	Pebbles out of the circles Pebbles inside the circles The pebbles on the lines of the circles I don't know
MATH	10. The session plan in mathematics is elaborated by:	Day Week month I don't know
ASER	11. The ASER test must be performed:	In small group collectively individually All these answers I don't know
ASER	12. How many level groups are constituted after the Aser test as well in mathematics and French?	5 groups 4 groups 2 groups 3 groups I don't know Other:
ASER	13. What is the total duration of the Aser data transmission cycle?	13 working days 14 working days 15 days I don't know
ASER	14. What is the correct stream of Aser data transfer?	Facilitators - Director - CPPP - Statistician in IEPP - National Coordination Facilitators - Director - Facilitators - CPPP - Statistician in IEPP - Coordination Regional - National Coordination Facilitators - Director - CPPP - Statistician in IEPP - Regional coordination - National Coordination I don't know
ASER	15. During the ASER test, a student was able to read the two paragraphs without error as well as the story. What is the level of the student?	History paragraph History and paragraph I don't know
MENTORING	16. The main purpose of visits to schools by mentors is to ensure that everything is going well and preparing reports for higher level officials.	True False I don't know
MENTORING	17. What is the role of the sector's mentor?	The mentor supports facilitators in the implementation of PEC activities and guarantees the proper functioning of the program. The mentor implements the activities of the in the classes The mentor only organizes monthly meetings I don't know
MENTORING	18. The sector's mentor organizes by month:	4 meetings 2 meetings 1 meeting I don't know
MENTORING	19. Mentor DEP organizes a week:	4 meetings 2 meetings 1 meeting I don't know
MENTORING	20: Mentor DEP visits each facilitator:	1 time a day 1 time a week 1 time a month I don't know

Tab. A.6.: Questions used for *NewMethod* motivation[7.5.2] analysis

CATEGORY	QUESTION	OPTIONS
NewMethod COMPETENCE	My school provided clear guidelines to us so that I know how to guide my students with *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod COMPETENCE	My school provided sufficient training to us so that I know how to implement *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod COMPETENCE	The timetable for implementing *NewMethod* was reasonable in my school so that I could do well on the task.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod COMPETENCE	My school took my workload into account, gave me room and time to do well on *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod COMPETENCE	There was good coordination in my school so that I could complete my *NewMethod* task smoothly	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod AUTONOMY	I was involved in formulating the direction and contents of *NewMethod*.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod AUTONOMY	My school sought teachers opinions widely in the process for *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod AUTONOMY	I participated voluntarily in the *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod AUTONOMY	I had a certain degree of freedom to decide how to guide my students for *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
NewMethod AUTONOMY	I felt that my opinions were respected in the process for *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
COLLEAGUE	I got encouragement from my colleagues when I encountered difficulties in *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
COLLEAGUE	Many colleagues shared useful resources for *NewMethod* with me.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
COLLEAGUE	Many colleagues shared their experience with me regarding the skills in supervising *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
COLLEAGUE	Many colleagues cared about the difficulties I faced in the process for *NewMethod*.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
COLLEAGUE	My colleagues and I made a concerted effort to implement *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
ADVISOR	I got encouragement from my pedagogical advisor when I encountered difficulties in *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
ADVISOR	My pedagogical advisor shared useful resources about *NewMethod* with me.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
ADVISOR	My pedagogical advisor shared their experience with me regarding the skills in supervising *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
ADVISOR	My pedagogical advisor cared about the difficulties I faced in the process of *NewMethod*.	Strongly agree Agree I don't know / No answer Disagree Strongly disagree
ADVISOR	My pedagogical advisor and I made a concerted effort to implement *NewMethod*	Strongly agree Agree I don't know / No answer Disagree Strongly disagree