Understanding the Longitudinal Impact of a Chatbot to Facilitate a Virtual Community of Practice for Teachers in Rural Côte d?Ivoire

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Communities of practice can improve teachers' professional development through informal in-person discussions among community members. However, infrastructural challenges pose difficulties in fostering in-person connections, particularly in rural communities in the Global South. The emergence of social media and chatbots has presented an avenue for creating virtual communities for teachers, especially those in rural areas. An unanswered question is the potential impact of a chatbot-supported virtual teacher community on teachers' professional development. To answer this question, we conducted a longitudinal quasi-experiment involving 313 teachers participating in a new training program in rural Côte d'Ivoire by deploying a chatbot on Facebook Messenger. Our experiment had two chatbot versions for two regions, i.e., one version supporting virtual community and one control. Our findings indicate that teachers in the virtual community condition exhibited modest enhancements in motivation and knowledge indicators. We make a case for implementing virtual communities of practice facilitated by chatbots to bolster the professional development of teachers in rural African contexts.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; • **Applied computing** → *Education*.

Additional Key Words and Phrases: HCI; ICTD; HCI4D; Teachers; Teacher Training; Chatbot; Community; vCOP

1 Introduction

Teacher professional development literature has long advocated for informal teacher communities of practice that lead to unstructured social learning [16, 71]. Prior work [60] suggests that collaboration and relationships with other teaching community members help teachers shape their work. However, teacher communities in the Global South have infrastructural limitations, such as financial means, roads, and vehicles, preventing teachers from regularly meeting their teaching community in person, thus limiting community interactions. Today, the expansion of technology has allowed opportunities for creating virtual communities of practice for teachers using social media [90, 102]. Notably, teacher support groups on WhatsApp have been instrumental in fostering

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virtual teacher communities in both Indian [105] and African settings [67, 79]. Unfortunately, connectivity issues prevent streamlined access and participation of rural African teachers [67]. Therefore, it is still unclear if virtual communities of practice impact teacher professional development in rural African contexts.

Effective teacher professional development promises better-trained and motivated teachers, but it faces challenges when training educators in the Global South [99]. The implementation of teacher professional development programs, especially in rural and isolated areas, encounters difficulties due to both infrastructural [19, 48] and socio-cultural complexities [61, 93]. For example, in African contexts a teacher may receive a one-week training and are subsequently expected to implement the program with limited mentoring [19, 25]. While mentoring is provided through regular visits of pedagogical advisors acting as administrators [48], infrastructural challenges and a shortage of mentors reduce the frequency of these sessions [19, 68]. Recognizing technology's potential in aiding teachers in the Global South [47], both government and non-governmental organizations (NGOs) are investing in teacher training and technology integration [67, 105]. While there's initial evidence of technology impacting teachers' professional development positively [25, 26], the long-term impact on teacher motivation and pedagogical knowledge necessitates thorough assessment of such technological interventions.

Conversational agents, also known as chatbots, have seen initial success with teachers in rural African contexts [26]. An exploratory deployment by the authors of a conversational agent on WhatsApp in rural Côte d'Ivoire [25, 26] found initial evidence that such technology can provide personalized and context-specific support to teachers. Recent research has allowed chatbots to support virtual communities of practice using innovative AI techniques in Western settings [45, 88]. These results are promising and motivate our choice of conversational agents. However, AI research is often disconnected from low infrastructure contexts due to socio-cultural nuances [87]. Prior work has attempted to bridge this disconnect [26, 49, 64, 116] through qualitative design studies with stakeholders. Despite these attempts, the longitudinal impacts of conversational agents and their ability to foster virtual communities of practice in rural African contexts are still unexplored.

To address the literature gaps in the impacts of virtual communities of practice and conversational agents for teachers in low infrastructure settings, we conducted a longitudinal study to evaluate the impact of community support designs in a chatbot on Facebook Messenger. Our study involved a year-long quasi-experiment with 313 teachers in rural Côte d'Ivoire to investigate the impact of two variations of a chatbot. One variation supported a virtual community of practice (vCOP); the other was a traditional agent that acted as a control. We evaluated the impact of our intervention on teacher motivation, teachers' pedagogical knowledge, and technology adoption. Our paper addresses the following research questions.

RQ1: *How do teachers use a chatbot that supports a virtual community of practice (vCOP) in low infrastructure settings of Côte d'Ivoire?*

RQ2: *How does a chatbot that supports a vCOP impact teachers in low infrastructure settings of Côte d'Ivoire?*

Our contributions to the COMPASS and HCI community include:

(1) We ran a rigorous longitudinal quasi-experiment in rural African contexts with a vCOP and control for over a year. We reveal how teachers use such a system longitudinally to ask questions, share stories, and adapt their teaching practices.
(2) We demonstrate moderate improvements in teachers' motivation and knowledge components. We also show that active chatbot users improved a specific pedagogical knowledge component.

Our study extends prior work by the authors in Côte d'Ivoire [25–27], which provided the initial need finding [27] and exploratory deployment [25, 26] to motivate this work. Through our paper, we make a case for virtual communities of practice and conversational agents to bolster support for teachers in low-infrastructure settings.

2 Related Work

This section summarizes the related work spanning teacher professional development, technology to support teachers in developing contexts, and chatbots for low-resource contexts.

2.1 Teacher Training and Communities of Practice

In recent years, developing countries have directed substantial investments towards innovative pedagogical approaches aimed at addressing the educational needs of primary school students [47]. These programs are designed to impart foundational skills to students, specifically tailoring the instruction to align with their individual learning levels [97]. Teachers have emerged as pivotal figures in ensuring the sustainability of these programs, particularly within the context of sub-Saharan Africa, where the programs' effectiveness has been well-documented [2, 5]. African governments have seamlessly integrated these initiatives into their teacher professional development frameworks, leveraging existing infrastructure for program implementation [2, 5, 47].

A significant body of work in teacher professional development literature believes that professional development is informal, and teachers learn through interactions between themselves [36]. Prior work has explored creating formal learning communities, but creating traditional structures is not sustainable as it takes more resources [42]. Additionally, learning occurs in a context, i.e., informal discussions among teachers during school hours [63]. Therefore, research has advocated for promoting informal teacher communities that allow unstructured social learning [16, 71].

Prior work has used a theoretical framework called communities of practice (COP) to understand informal teacher communities [112]. 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 [112] postulates that repeated interactions between new and active members allow new members to learn and become active eventually. Wenger [112] 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 [59]. Lesser & Prusak [60] argue that collaboration in COPs helps build relationships with other community members, which helps them learn and shapes the future direction of their work. Creating unique channels that allow for meaningful conversations between active and novice teachers also leads to novice teachers' learning and integration into the community [35]. Lastly, these conversations have to be sustained over time to create a meaningful impact on teachers' learning [76]. 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 [48]. Therefore, the literature suggests augmenting existing COPs with technology [47, 90].

2.2 Virtual Communities of Practice for Teachers

Virtual communities of practice (vCOPs) use online technology to allow communities to interact beyond geographical limitations [78]. A vCOP uses technology to allow for virtual participation among members to share stories and have discussions to solve problems related to their domain [52]. 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 [78]. Prior research has shown that it is normal for a large section of users in online communities to participate peripherally [80]. Still, peripheral participation is essential as members learn from reading information that may not be available elsewhere [40].

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 [91]. To design virtual communities, prior work [44] 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. [113] 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 not necessarily how it was designed to be used [78].

Research on vCOPs for teachers has 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 [90, 102]. To support teachers' access to resources, prior work recommends personalized interactions that cater to each teacher's needs [90]. On the social side, experienced teachers (or teachers with higher self-efficacy) are likelier to share content [102]. Sharing on online media is motivated by offline interactions, and technical systems would benefit from increased social interaction between novices and experienced teachers [102]. Although vCOPs have supported teachers in Western contexts, it is unclear how technology can support teacher communities in low infrastructure context [6, 7] where internet access may influence technology adoption and usage.

2.3 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 [56, 74, 104] or supporting school administration [9, 11, 83]. Prior projects that focus on teachers have helped them with *teaching resources* through video content [14, 62, 86], audio content [10], and text messaging [53]. Still, it is unclear whether providing teaching resources supports teachers in implementing novel pedagogical programs [47]. Additionally, introducing new technology requires extra digital training and monitoring to promote engagement [62].

Prior work has mitigated training and monitoring costs using popular social media applications, such as WhatsApp, which is a familiar tool for teachers [46, 65, 79]. In Indian contexts, NGOs have extended technology support beyond teaching resources by creating groups [12] to foster peer support and remote administrative help for a vCOP of teachers [70, 105–107]. In particular; these initiatives showed success in decreasing teacher absenteeism.

However, internet technology [26, 27, 65] in rural Africa is still lagging behind its Global South counterparts like India [6, 7]. In rural Côte d'Ivoire, a related project by Motteram et al. [67] found initial evidence that Whatsapp groups could support the vCOP of language teachers. Still, rural teachers lagged on usage due to connectivity issues. [67]. Teachers use the internet infrequently in rural contexts or specific locations due to sparse cell tower infrastructure and higher cost of internet data plans [24, 67]. 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 still growing [6, 7].

2.4 Chatbots in low-infrastructure settings

Chatbots or conversational agents can disseminate expert knowledge at scale by applying artificial intelligence (AI) [26, 41, 110]. Chatbot research dates back to 1966 with the development of Eliza, which sought to emulate the role of a therapist using rudimentary rules of language understanding [111]. Chatbots have proliferated across various platforms and are utilized by approximately 1.4 billion users, finding their presence on home assistants and social media platforms like Skype, WhatsApp, and Facebook [38, 92]. Facebook Messenger alone boasts an estimated 300,000 chatbots [92]. Previous research endeavors have explored strategies to enhance the capabilities

of chatbots by employing human-machine hybrids [41] or 'humbots' that complement expert knowledge with innovative AI techniques [45]. Furthermore, studies have expanded the scope of chatbots through Crowd-AI hybrid architecture, allowing for automated conversations over time, with crowd workers stepping in to assist when AI encounters difficulties in generating an appropriate response [45]. Additionally, chatbots have been employed to mediate experts' critiques of learners within short time intervals on social media platforms [99]. In education, a chatbot has been deployed to foster a community of practice for teaching staff in the United States [85].

However, most of this work is focused on Western settings and the English language [92], which may not seamlessly transfer to developing contexts owing to language datasets and translation support limitations, thereby increasing reliance on human experts. Within developing contexts, prior work has centered on voice-based chatbots tailored for low-literacy users [50], and has explored design possibilities for urban novices interacting with chatbots via Facebook Messenger [51]. More such research is needed in Sub-Saharan countries like Côte d'Ivoire, where the language and low telephone infrastructure in rural contexts affect technology design [6, 27]. HCI4D research proposed to bridge this disconnect [26, 49, 64, 116] by uncovering design ideas through qualitative studies, but research on chatbots is still emerging. A few exploratory studies by the authors have opened design directions for chatbots in Côte d'Ivoire [25, 26]. However, our prior studies did not seek to understand the impact of chatbots on teacher professional development nor engage in understanding of longitudinal use. Furthermore, they weren't studied in the context of virtual communities of practice.

In sum, teacher communities can support teacher professional development through organic, informal expert-novice interactions but are limited by geographical constraints. Recent literature has shown promise for technology to transcend geographical limitations through virtual communities on social media, facilitating teacher interaction through chat. However, these virtual communities still face the bottleneck of including rural teachers due to their lack of literacy skills and lack of moderators. Prior work on chatbots has shown promise to improve participation from rural teachers in virtual communities. However, it is unclear how rural teachers will use such systems longitudinally and how such a chatbot will impact teachers' professional development.

3 Research Questions

The central questions of our study are:

RQ1: *How do teachers use a chatbot that supports a virtual community of practice (vCOP) in low infrastructure settings of Côte d'Ivoire?*

RQ2: *How does a chatbot that supports a vCOP impact teachers in low infrastructure settings of Côte d'Ivoire?*

We classify the impact into three distinct categories: (1) the adoption of technology, specifically referring to teachers adopting the chatbot; (2) the motivation of teachers for teaching; and (3) the knowledge and skills of teachers pertaining to the training program. We hypothesize that the community support provided by fellow teachers in the virtual Community of Practice (vCOP) condition will result in an increase across all three categories:

H1: Technology adoption will increase with community support. Building on previous work in ICTD [77, 116], we hypothesize that technology adoption will increase in the vCOP condition. The extensive literature on asset-based design [77] emphasizes that technology adoption is more effective when designed around users' strengths. In our context, we had discovered in our prior work that community interactions [25, 27] among teachers was a core strength. Additionally, in prior work in Côte d'Ivoire, teachers highly appreciated the community-based interactions on social media [25, 26, 67]. Therefore, we expect to see improvement in the adoption among users in the community support condition.

H2: Teacher motivation will increase with community support. Drawing insights from prior meta analysis [94], we hypothesize that providing teachers with community support will result in increased motivation. Existing

literature suggests that when teachers have access to a supportive community, their motivation tends to rise due to the expansion of support networks and a heightened sense of encouragement [15]. This heightened motivation is expected to be reflected in an increased sense of agency within the community [98], enhanced self-efficacy in teaching [30], and a simultaneous decrease in burnout levels [84].

H3: Teacher knowledge and skills will increase with community support. Building on previous research [13, 103], our hypothesis posits that community support plays a crucial role in enhancing teachers' knowledge and skills. A longitudinal study [103] indicates that participation in communities of practice is associated with an increase in teachers' knowledge. Furthermore, the presence of community support provides teachers with more opportunities to engage in discussions and learn from their colleagues [13].

4 Methodology

4.1 Study Design

This study is part of an ongoing research project [24–27, 114, 117, 118] 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 closely collaborated with an international NGO implementing a new teaching method in Côte d'Ivoire called *NewMethod* (we don't disclose the program to preserve the privacy of the communities). *NewMethod* is a classroom teaching method that significantly differs from existing teaching methods in Côte d'Ivoire. The NGO had observed success in some initial pilots in 2019 and was interested in scaling the *NewMethod*. Although *NewMethod* itself did not inherently use technology, our project was an initiative to learn the opportunities for scaling the deployment of *NewMethod* with technology. We received approvals from all our institutional boards (Carnegie Mellon University protocol *STUDY2019_00000510*) and the Ivorian government to conduct the study.

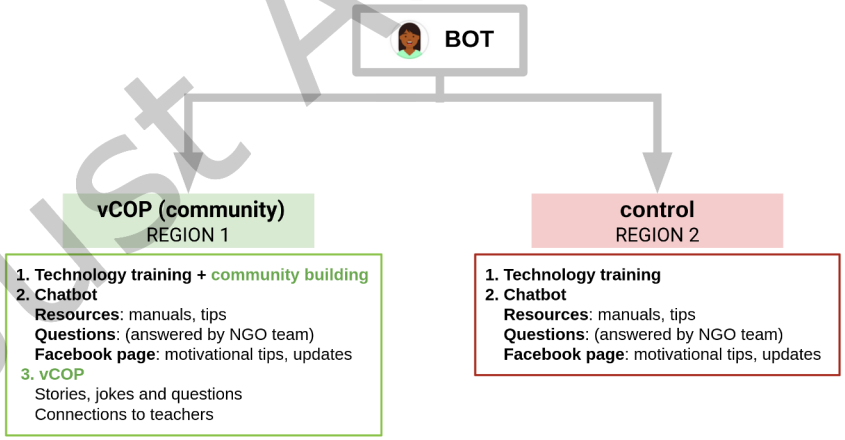

Fig. 1. Study design consisted of two regions assigned to the two conditions, i.e., vCOP and control. The vCOP condition had features that supported a virtual community by allowing teachers to interact with each other through stories, jokes and connections. The control condition only had traditional chatbot features where teachers could access resources and ask questions about *NewMethod*

We conducted a large-scale longitudinal study in 2021-2022 in the Southwestern region of Côte d'Ivoire. We deployed the chatbot to 126 schools across two regions (REGION 1 and REGION 2) with over 500 teachers who were trained in *NewMethod* and were implementing it for the first time. We followed a quasi-experimental approach to split teachers into two conditions (see Figure 1) by region, i.e., (1) (vCOP) Community support in REGION 1 and (2) Control in REGION 2. Both groups used the chatbot, but in REGION 1, the chatbot had vCOP features, while in REGION 2, these features were not present.

Since regions 1 and 2 were similar in several key aspects, we chose to randomize our intervention at the regional level. Both regions shared comparable socio-economic conditions, literacy rates among primary school children, and access to essential resources such as electricity and water. Additionally, access to mobile phones and internet was identical in both areas. We did not see any significant differences in the baseline surveys (see Table 11). The region's equivalence was also confirmed through our field partners, who supported our decision to implement the intervention randomly across the two regions.

Control condition had features to support teachers directly with the pedagogical programs. The chatbot 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 chatbot. 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.

vCOP (community) condition had all the features in the Control condition but also allowed teachers to connect with and support community members. We also added stories, jokes, and other community-oriented features that were valued in a prior deployment [24]. The vCOP content enabled teachers to view and share content with community members. Teachers' contributions were moderated and curated by the NGO worker. This group also received a community-building session at the beginning, which was a social activity that reminded teachers about their teacher community. Teachers shared positive stories about teaching with fellow trainers, first in person and then typed into the chatbot.

4.1.1 System Design. Our chatbot, named *DIA*[1] used a *humbot* architecture to answer questions from a database [26] of frequently asked questions about *NewMethod*. When the questions were in the database, they were responded to automatically and immediately by *DIA* (Figure 2 - 2a). However, when questions weren't in the database, teachers would receive a placeholder response telling them they would receive the answer shortly (Figure 2 - 2b). For unanswered questions, the NGO worker would answer the question from our dashboard (see Figure 9), and the NGO worker's answer would be shared with the user (Figure 2 - 3).

Additionally, we designed the chatbot to include menu based interaction, this design inspired by USSD menus[2], which are interactions familiar in African contexts. Users would be presented with a menu with numerical options, which would lead to subsequent menus or features. Users could use the menus to browse through various features. Figure 10 provides an example of menu-based interaction for accessing stories. Figure 3 shares a flowchart of all the chatbot features.

We developed our chatbot using the open-source software Rasa, a customizable chatbot framework [8]. Rasa interfaced with the Facebook API via FastAPI, a lightweight Python framework [3]. The system was hosted on an Ubuntu server [1], incurring a monthly cost of approximately *40 USD*. Leveraging Rasa allowed us to

[1]This chatbot was an improved iteration on our prior deployment [24–26], we moved the chatbot to Facebook Messenger because teachers found it to be more accessible. Additionally, we used a menu-based interaction to improve usability

[2]Unstructured Supplementary Service Data menus with numeric options are very popular in African contexts. For instance, they are used to recharge their phone credits

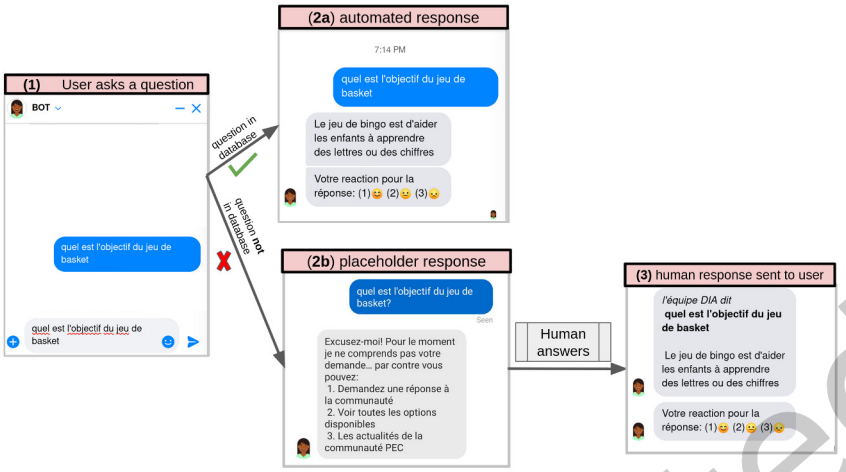

Fig. 2. A workflow of humbot architecture of *DIA*. (1) The user asks a question. (2a) When the question is in the database, the user automatically receives the answer. (2b) When the question is not in the *DIA* database, the user gets a temporary response (3) Later, the NGO worker answers the question from the dashboard (see Fig 9), and the user receives the answer

assign responses to predefined question categories for anticipated interactions. For instance, common exchanges included "greetings" based on prior contextual work [25], such as wishing good morning or good evening before interaction. We also created question categories for inquiries related to *NewMethod*, information about the agent, and study goals.

4.2 Chatbot Menu Design

Our chatbot designs were motivated by prior chatbot deployments in the context [25, 26, 67], which hinted at simpler designs as teachers were still learning to use smartphones. Prior work in Côte d'Ivoire also expressed the importance of community among teachers [25, 27]. Specifically, teachers were using technology such as social media or traditional phone calls to support each other in their teaching practices. Thus, our chatbot designs were motivated by these findings to understand the impact of such systems and their ability to foster community support.

- **Introductory tutorial**: We expanded the introductory survey and messages to guide the users through the various features of the chatbot. The new tutorial gives teachers a prompt to type the appropriate menu option. We followed Kraut's suggestion [57] 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.
- **Simple menu structure**: We used concise text (*NewMethod tips and manual* instead of *NewMethod information*). We also found that teachers found it hard to read the entire text. Therefore, we used emojis in the first letter to help teachers quickly grasp the menu content. We also tweaked the Facebook messenger settings to display a button:*Tap 0 for home* whenever teachers opened the chatbot. Tapping the button would open the home menu, thus allowing teachers to continue navigating the chatbot.
- **Community Menu**: 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

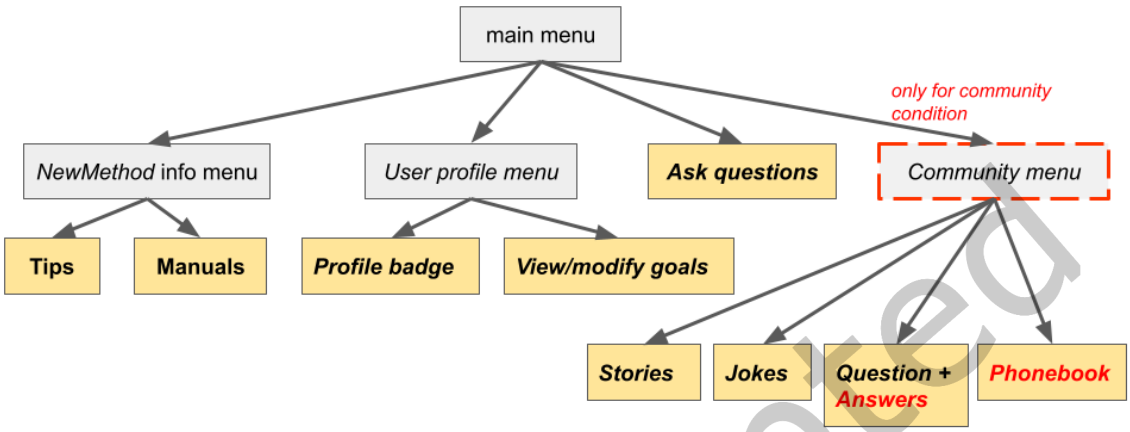

Fig. 3. Flowchart of system features used in the study

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.

- **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 chatbot. If the NGO worker responded to the question, the answer would be sent via the chatbot to the teacher who asked the question and again as an SMS since teacher's may not always have internet data available for the chatbot. 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 chatbot. We expressed using emojis that the system was open to image, voice, or text-related input. Our partners also informed us that directors in internal WhatsApp groups would share photos of *NewMethod* activity.

4.3 Background on *NewMethod* and Teacher Training

The *NewMethod* program, implemented by an international NGO, focuses on enhancing basic math and French skills among 3rd, 4th, and 5th graders. Initially, school teachers administer a baseline test to categorize students into three proficiency groups. Throughout the academic year, the teachers engage these groups in daily 45-minute

sessions designed to improve French and math skills through playful, hands-on, child-centered activities. Progress is monitored with additional assessments conducted in the middle and at the end of the year to track student improvement.

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. Teachers are supported by school administrators who provide mentorship on *NewMethod* during their official interactions with the teachers. Directors (senior school teachers) act as additional in-school mentors. Senior officials such as pedagogical advisors and inspectors support teachers on *NewMethod* during their regular school visits.

Fig. 4. This scene depicts a standard *NewMethod* activity where students are organized into groups based on their skills in French and math. Each group partakes in engaging, interactive, child-centered lessons for 45 minutes per subject daily, facilitated by their instructor.

Teachers receive training for *NewMethod* in week-long workshops before implementation during the start of the year. *NewMethod* program required a cultural shift from teachers because the traditional teaching methods involved structured formal lectures from the curriculum, while *NewMethod* required teachers to be informal. The curriculum is driven by working with the students. Thus, the *NewMethod* requires a radical shift in their approach. Hence, they needed more support beyond the one-week training, such as when they had questions. Additionally, prior work [25, 27] by the authors found that teachers were often isolated in such programs because of the need for more administrative support in professional development over the academic year. However, the teaching community played an active role in providing support.

Thus, as the Ivorian government looked to expand the scope of *NewMethod*, the NGO was open to interventions such as technology [26] to support teachers better.

4.3.1 Program Implementation. We trained the teachers to use the chatbot 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 team visited a site 1-2 times during the *NewMethod* training week to conduct chatbot workshops. Each chatbot workshop involved an hour-long session, which involved

Table 1. Table summarizing the 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[5.2]	313	178	135
Motivation survey [5.3]	143	82	61
Knowledge survey [5.4]	91	51	40
Interviews	12	6	6

onboarding and practicing different features of the chatbot. The control condition had two general practice sessions, while the community support condition had one practice session and one community activity.

After *NewMethod* training, teachers were required to implement the *NewMethod* method daily as part of the administrative rule in the selected schools. Daily, 45 mins were allocated for a Math activity and 45 mins for French. Teachers were not provided any financial incentives to implement *NewMethod*. Teachers also received mentoring visits from ministry officials and the NGO during the year. During visits, the mentors observed teachers implement *NewMethod* and provided them with constructive feedback.

Beyond the training, teachers were sent regular reminders through text messages and posts from the Facebook page to motivate them to use the chatbot. Teachers who shared their numbers on the chatbot were sent text messages with motivational messages throughout the year. We sent text messages during periodic events such as student tests and the 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 showing examples of teachers working together for *NewMethod*. We also posted 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.

4.4 Participants

Table 1 summarizes the data sources for the two regions collected to answer the various research questions. 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. A handful of urban schools were near the main regional city, while the rest were scattered among rural outlying communities.

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[3]. 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.

4.5 Measures

The data for the study was collected through surveys, interviews, and *DIA* log data during the academic year. The data was collected in five stages, and the table 2 summarizes the collected data and research questions.

H1: CHATBOT ADOPTION. We analyzed chatbot adoption through cumulative interactions, setting a threshold for active users. We assessed chatbot adoption by analyzing the cumulative sum of interactions. We gauged adoption by considering the total number of messages each user sent throughout the year. We established a threshold based on the minimum *DIA* survey responses to distinguish between active and inactive chatbot users.

[3]6th grade teachers were added in this specific implementation of *NewMethod*

Table 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	KNOWLEDGE & SKILLS
	teacher and director interviews	ALL
Endline	June 2022	Collected endline data for research
	endline survey	MOTIVATION KNOWLEDGE & SKILLS
	teacher and director interviews	ALL
	stop chatbot deployment	CHATBOT ADOPTION

We defined active chatbot users to be participants who sent over 33 messages or engaged with the chatbot after training.

H2: MOTIVATION. To understand teacher motivation, we had survey questions on teachers *agency in the community* [81], *self efficacy* [89], *burnout* [23] and *perceived social support* [43], .

Agency in the community consisted of 16 questions investigating teachers' professional agency in their professional learning community [81]. This questionnaire was created and validated with teachers in Finland [81], but has since been used across contexts such as the US, New Zealand, China, and Taiwan. It consisted of four subscales: *transformative practice*, *collective efficacy*, *positive interdependence*, *active help-seeking*, and *proactive strategy*.

Self-efficacy was based on the self-efficacy questionnaire by Bandura [17]. Our questionnaire consisted of 10 questions created specifically for teachers and validated in Syria and Germany [89], and later tested globally, including in Nigeria, China, and Israel.

Burnout was measured based on Maslach's 22-question burnout inventory [23]. We used a modified version of this scale intended for educators, tested on teachers in Cyprus [55]. This version has been tested on teachers in Ghana, the United States, and Scotland, among others. Subscales include *personal accomplishment*, *emotional exhaustion*, and *depersonalization*.

Perceived social support consisted of 4 questions about colleague social support inspired by the multidimensional scale of perceived social support [119]. The original scale [119] was modified and validated on Chinese high school teachers [43] to understand support from colleagues, school principals, friends, and family, and then tested in Greece, Colombia, and Hong Kong. We used the 4 questions that were specific to colleague support [43] in this study.

After data cleaning for invalid and non-responses, 143 participants were present in two datasets collected at baseline and endline on teachers' motivation.

H3: KNOWLEDGE & SKILLS. The NGO created the knowledge questionnaire to evaluate teachers on *NewMethod*. The knowledge questions comprised four sections of five questions each for Math, French, *NewMethod-test*, and mentoring. The questions consisted of multiple-choice and true or false questions. After data cleaning, 91 participants were present in the four datasets collected at midline and end-line, which were used for analysis.

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

4.6 Data Analysis

Difference-in-Differences.

$$Y = \beta_0 + \beta_1 * g + \beta_2 * t + \beta_3 * (t * g) + \sum_{i}^{n} \beta_{i+3} * Covariate_i + \epsilon \quad (1)$$

We used the above standard difference-in-differences [28, 39] equation in regression form where $g = 1$ was used for the community group condition, and $g = 0$ was used for the control group condition; and data in the baseline had $t = 0$, while data in the endline had $t = 1$. 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 (H2) and teacher pedagogical knowledge (H3).

Covariates The datasets for control and community conditions were equivalent at baseline, as there was no statistical significance for relevant variables, such as gender, teaching grade, smartphone experience, and internet expenditure at baseline (See Table 10). Therefore, no *Covariates* were used for Motivation (H2). However, for Knowledge (H3), *time in weeks* was used as a covariate as there were four different data points. The errors were clustered [39] by village and school level.

Analysis variables[4] *- 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.

We used the log data to create two exploratory analyses to understand the effects on motivation and knowledge from active chatbot users. The first analysis variable (A1) is to help understand the motivation (H2) hypothesis. A1 analysis consisted of active users in "vCOP" who used the community features and all users in the control condition. The second analysis (A2) was used to understand the knowledge (H3) hypothesis. A2 was used for comparing all active users, i.e., users who used the chatbot and inactive users. Since instruction from the chatbot was common to users in both conditions, the A2 analysis compared active and inactive users to understand the change in knowledge.

Simple matching. or average treatment effect [75] was used in chatbot adoption. 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. The log data provided the cumulative number of

[4]The analysis variables A1 and A2 were inspired by instrumental variable [39] 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.

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.

Qualitative Analysis. We used qualitative analysis to analyze the (1) specifically mixed-method [21, 31, 32] for interviews and (2) the chatbot log data.

Qualitative analysis for the interviews aimed to explain the quantitative data. We used a mixed-method approach [31] where we used the qualitative findings to contextualise the quantitative data from the survey [21, 32]. First, we transcribed and translated the interview data from French to English. The first author went through the transcripts and formed the codes using an inductive approach [20, 29, 69, 95]. As a group, we considered the relationship between the codes and categorized them according to the main research questions. Some codes were "*NewMethod* motivation: challenges: additional workload, *NewMethod* knowledge: manuals help with learning". We then discussed the codes and the quantitative results with our research collaborators and modified the codes based on our discussions. Some final codes were "aspirations: tech literacy is helpful for exam preparation" and "tech adoption: offline usage is helpful". These codes were 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. The chat 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.

Self-Disclosure. We expect our individual experiences, research process, and goals to have shaped the research. Our team consists of HCI researchers, economists, and linguists. Our experience, approach, and goals will affect the data analysis. The research team was based in the US and Rwanda and had extensive experience conducting research in African countries. The first author is from a developing country, and they formed the protocols and analyzed the data after discussions with the Ivorian team and faculty. We had weekly interactions with the local team to seek feedback on the analysis. Additionally, our goal with the future study is to evaluate the effects of quality education (chatbot and *NewMethod*) on students at scale.

5 Findings

5.1 RQ1: CHATBOT USAGE

Before investigating the effect of the vCoP, we looked at how participants across both groups used the chatbot. This section discusses how all 313 participants who engaged with the chatbot used the different features over the year.

Teachers sent 111 messages (standard deviation: 179) per week throughout the 30-week deployment (see Fig 5). 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 *NewMethod-test*, i.e., student evaluation conducted by the teachers in baseline, midline, and endline. Teachers also used the chatbot during holidays when school was closed. Teachers interacted with the chatbot during Christmas and Easter, sending seasonal greetings to the chatbot(*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.

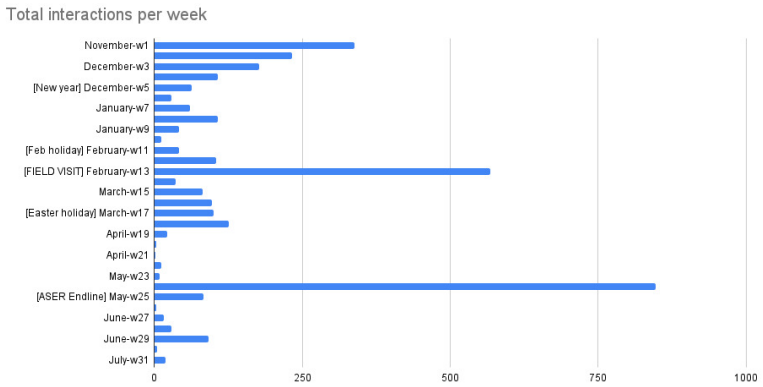

Fig. 5. Shows the total number of weekly messages by 313 teachers. Note: These messages include questions and menu interactions, which include reading other teachers' stories, reading tips, and downloading manuals.

5.1.1 Teachers used the chatbot to ask questions, access documents, and prepare lesson plans. Teachers used the chatbot to ask specific queries about the teacher training program when they faced challenging situations. Teachers found both automated and human responses to be useful. They noted that the speed of automatic responses was important to them; typically, getting support involved a long wait for a visit from a pedagogical advisor. Teachers mentioned, however, that they were willing to wait for human answers when they faced more challenging difficulties while implementing *NewMethod*. They mentioned that the chatbot was a resource to resolve those 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**

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. Some teachers traveled during weekends and holidays to their families in remote areas without internet infrastructure. Teachers described how offline access to Math and French training manuals helped them 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**

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 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 the chatbot questions. Directors who supervised these meetings mentioned that they observed teachers using the chatbot when they had questions from these meetings.

Table 3. 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	80.0	81.57	18.43	

Table 4. showing different codes answered on the chatbot

CODE	COUNT	PERCENT
GREETING	39	26.7
OTHER	24	16.4
NewMethod-test	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	

5.1.2 Teachers engaged the chatbot in social conversation, asked logistical and philosophical questions. Teachers asked 255 questions over the year. The NGO worker or the chatbot answered most of the questions (208, or 81.57%). Table 3 summarizes the questions provided by the NGO worker (human answered), chatbot, and unanswered questions. The chatbot drew answers from a database we created from a prior set of teachers' questions related to *NewMethod*, including basic information about the teaching method, greetings, and other simple interactions. The chatbot provided automated answers immediately to 65 of the questions. The NGO worker answered the question using a web-based dashboard. The dashboard presents questions in red which change to green upon answering, and the answer provided is displayed (see Figure 9 in the Appendix). The NGO worker using this interface answered 204 out of the 208 total answered questions (98%), meaning that even after the chatbot answered in almost all cases, the human responded as well. The NGO worker responded to queries related to *NewMethod* activities, session planning, and *NewMethod-test* tests. 47 questions went unanswered. The unanswered questions consisted of errors and queries beyond the NGO workers' scope, to which they chose not to respond, or the questions were asked when traveling to rural areas without internet access, leading them to miss the question.

After data cleaning and merging, 146 questions the chatbot answered were unique, as summarized in Table 4.

The most popular category was *French activity* (11.6%). Teachers asked questions about implementing a specific *NewMethod* 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 for their context. 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 *NewMethod-test* (11.6%), where teachers asked about the *NewMethod-test* implementation. These tests were used to group students into levels based on their performance, and teachers were required to conduct them three times during the year, i.e., at baseline, midline, and endline. Teachers asked questions about grouping students, implementation details, and requested documents. Teachers asked questions about (1) Grouping students after the initial *NewMethod-test*. For example, teachers asked questions when they found students who did not fit the hierarchy set by *NewMethod*. (*Where to classify the students who do not recognize the numbers but manage to divide? - Q14*). Teachers also asked questions about (2) specifics of *NewMethod-test* implementation. For example, teachers were interested to know if they should use the same set of questions for baseline and midline for a particular student (*Should we use the same number of the NewMethod-test tool for the student in this midterm? - Q70*). Lastly, teachers asked about (3) the different documents to implement and record the student test. There were specific documents, similar to attendance sheets, to record *NewMethod-test* and report information to administration- (*I want to know how to complete the NewMethod-test endline document?. -Q77*)

Teachers also asked about preparing a session plan (SESSION PLAN: 9.6%), a document for preparing weekly lesson plans for *NewMethod*. Teachers requested information about session plan documents. For example, teachers were interested in the official example session plans - (*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%). As noted above, 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 chatbot, 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 wanted to go beyond logistics to understand what they were doing and why more deeply. They 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*). They 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 are the details of DIA- Q21*).

Finally, the last category consisted of questions that were text providing feedback about the *NewMethod* program (16.4% OTHER). The feedback included stories, jokes, and goals. 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.*). We also classified teaching questions about the traditional pedagogical methods, outside the program's scope, in this category, such as (*What is the lesson's objective in multiplication at CE1 - Q80*). The NGO worker chose to respond that the system only supported *NewMethod* knowledge.

After understanding how the chatbot was used in general, we then investigated specifically how the community group used the community features.

5.1.3 Community support allowed teachers to learn from and support fellow teachers digitally . The teachers in the community group 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 as part of the *NewMethod* training activities.

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

Teachers also shared personal stories about their prior teaching experiences in traditional teaching. These stories centered around their struggling students with whom the teachers had developed a personal connection in the past.

> One afternoon, a student returned with a tight face; I asked him about it. He answers Ma'am, I haven't eaten since morning. So I offered him bread. Since then, I have been nicknamed Maman Cantine. - S230

After the training, teachers shared stories about the positive outcomes of *NewMethod* implementations. The stories reflected behavior change among students as observed by teachers after experiencing the program. These stories reflected how students become more attentive, punctual, and collaborative due to 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

The community feature allowed teachers to share knowledge and motivate 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 answers from the dashboard and approve the messages. The chatbot sent an automated approval message to the submitter when moderators approved teachers' submissions. Teachers mentioned they appreciated it when the chatbot accepted their submissions.

> Yes, one of my colleagues has shared his question 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**

5.2 RQ2: IMPACT - H1: CHATBOT ADOPTION

5.2.1 Technology adoption was affected by poor internet access, outdated smartphones 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 as teachers often needed to travel over an hour to reach cities and access the chatbot. This finding is similar to prior work [25, 26, 67] in the context and extends the access issues for longitudinal settings. 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 stay connected. 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**

Teachers also had device issues that negatively affected chatbot usage. Teachers had outdated Android devices and old versions of Facebook 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, smartphones often have physical limitations, such as cracked screens or defects affecting phone usage. Although such devices could be used for basic utility, such as taking phone calls, it was hard to use advanced applications like social media.

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. They also believed their interest in learning this technology would motivate 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**

5.2.2 Technology adoption was reduced by offline access and external 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 *NewMethod* 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 learned that teachers found it challenging to find the PDF manual as the message with the manual would be shadowed by the plethora of messages shared by multiple participants. Teachers in the control mentioned they needed more utility from the chatbot 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, not all teachers have an internet connection or a smartphone. -**T35 (control)**

We found that teachers in control and community 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. Our Inspectorate has our *NewMethod* groups; we communicate on these WhatsApp groups. We share information, send each other messages, and share new documents. - **T184**

The next section compares technology adoption across the community(vCOP) and control conditions. The net

Table 5. Summarizing technology adoption across the two conditions

variable	Average 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

usage difference wasn't statistically significant despite a higher average in the community condition. Using simple matching, we found that teachers in the community condition sent more messages than the control condition, but the results were not significant. On average, teachers in the community condition sent 33.6 messages compared

to 25.6 in the control condition over the study duration. The difference was 8.12 messages but wasn't statistically significant (p=0.17). Active users sent 61.84 messages, and inactive users sent 4.33 messages.

The reported usage was higher in the control condition, 4.6 vs. 3.9 in the community region, but this change 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 2.00.

5.3 RQ2: IMPACT - H2: MOTIVATION

Our finding below describes the need for teacher motivation in *NewMethod* due to increased workload, lack of resources, and disruptions:

5.3.1 NewMethod Implementation increased teacher workload. 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 teaching the curriculum for the grade before the end of the academic school year. Alternatively, *NewMethod* focused on foundational learning, i.e., *NewMethod* activities involved supporting students' recovery of basic math and French skills despite their grade level. The conflict in philosophy led to practical challenges, such as additional workload on teachers, thus impacting teachers' overall well-being. Although teachers valued the benefits of *NewMethod* for students, they felt they needed additional motivation to implement *NewMethod*.

> *NewMethod* has not lightened our workload, but it 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**

Teachers were affected by the lack of resources and additional administrative responsibilities, which interfered with the quality of *NewMethod* 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 only implement a subset of *NewMethod* activities, or students had to share material, thus reducing the quality of implementation. 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. Teachers mentioned that they implemented *NewMethod* activities concurrently, so teachers had only had the Friday meetings to interact with each other about *NewMethod* and solve challenges collectively. Therefore, missing these meetings made finding opportunities during the week to discuss *NewMethod* issues as a group difficult.

This finding contextualizes the additional workload on teachers due to novel teaching methods, leading to the need for additional motivation and importance of community support for the teachers. In the next sections, we determine the impact on teacher motivation across two groups, across the various subscales of motivation.

5.3.2 Perceived social support: There was an increase in perceived social support within the community condition; however, a marginal level of significance was evident in the A1 analysis involving active users. 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).

Table 6. Shows the differences in differences and analysis variable (A1) for the various survey scales in teacher 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	did (%)	p value
perceived social support	82.9	82.7	83.1	78.4	4.2	0.200	7.4	0.079
self efficacy	84.9	81.5	83.2	81.2	-1.6	0.316	-0.8	0.670
agency: transformative practice	86.9	89.6	88.7	87.7	4.2	0.175	9.7	0.012
agency: collective efficacy	87.9	91.4	91.0	89.8	3.8	0.157	5.4	0.141
agency: positive interdependence	88.5	94.8	94.3	93.2	5.9	0.028	8.4	0.041
agency: active help seeking	86.3	91.8	90.5	91.6	5.5	0.080	8.1	0.073
agency: proactive strategy	86.0	92.7	91.5	89.4	6.9	0.026	10.9	0.006
agency: combined	87.2	91.9	91.1	90.1	5.1	0.041	8.4	0.016
burnout: personal accomplishment	95.7	95.6	93.2	96.4	-2.3	0.251	-2.1	0.313
burnout: emotional exhaustion	33.8	35.3	31.4	34.3	-3.4	0.088	-4.6	0.045
burnout: combined	-27.0	-25.5	-27.7	-26.9	-1.9	0.412	-3.2	0.206

did (%) indicates difference in differences in percentage.
p value <0.05 is considered significant, p value < 0.1 is considered marginally significant.

5.3.3 Self efficacy: There was no significant change in self-efficacy over time in the community condition. The average endline for *self-efficacy* in both conditions reduced compared to the baseline. An exploratory analysis (A1) comparing active users in the community and the control users did not yield any significant results

5.3.4 Agency in the community: Over time, the community condition exhibited a significant increase in the *combined agency*, particularly in sub-scales of *positive interdependence* and *proactive strategy*, compared to the control condition, with active users showing similar trends. 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 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. There were no significant changes in the other sub-scales.

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* showed no significant results.

5.3.5 Burnout: Although the community condition showed a slight reduction in overall burnout, a notable decrease in emotional exhaustion suggests an improvement compared to the control condition. 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. Examining the burnout subscales, we observed no significant results for *personal accomplishment*. 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 *emotional exhaustion* indicates decreased burnout in the community condition compared to the control condition.

The A1 analysis showed non-significant overall burnout changes but a marginally significant increase in emotional exhaustion for active users. An exploratory analysis of the comparison between active users in the

community condition and all users showed no significant results. For A1 analysis for sub-scales of burnout, we observed a decrease over time for *personal accomplishment*, but the results were not significant. 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, and the results were marginally significant. The Cronbach alpha for *depersonalization* in burnout was low (0.23) (see Table 9), indicating that the scale is not valid in the context and hence was discarded in the *combined burnout*.

In the following section, we present insights from teacher interviews, highlighting the significance of community interactions in fostering teacher motivation. Our findings indicate that offline and social media-based community interactions contribute to improved collaboration, learning, and motivation for effective implementation of *NewMethod*.

5.3.6 Community interactions offline, on the chatbot, and other social media supported teachers. 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 and receive support remotely. Teachers would call their colleagues or advisors to seek help based on their availability.

Teachers mentioned that they would often visit the chatbot for stories that they found resourceful and 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, examples, 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. (in *NewMethod*) - **T372**

Additionally, community interactions on external social media, such as WhatsApp groups, helped teachers with *NewMethod*. WhatsApp provided informal and formal avenues to seek support on *NewMethod*. Teachers had organically created WhatsApp groups in their inspectorates, 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 on their content from the teaching community. The groups helped create a sense of motivation and a sense of belonging. Therefore, more such community interactions could support teacher's professional development.

> 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**

5.3.7 Community multimedia on the DIA Facebook page helped refresh knowledge and motivate teachers. Teachers mentioned that the multimedia on the Facebook page was a valuable resource to support *NewMethod* implementation. Teachers could refresh their knowledge of the program by looking at the pictures to observe their colleagues, especially when teachers faced difficulty accessing specific topics from the *NewMethod* manual and required additional support. For example, implementing *NewMethod-test* was not shown in the manual, and teachers could only gain the 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 *NewMethod-test*.

> I was absent when they showed us how to do the *NewMethod-test* because I came late. So, I used images on the Facebook page to help me implement the baseline *NewMethod-test* 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**

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 norms of an acceptable variant. The multimedia on the page provided examples for teachers to adapt their implementation. Teachers observed behaviors from other teachers implementing and adapting the *NewMethod* program.

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**

5.4 RQ2: IMPACT - H3: KNOWLEDGE & SKILLS

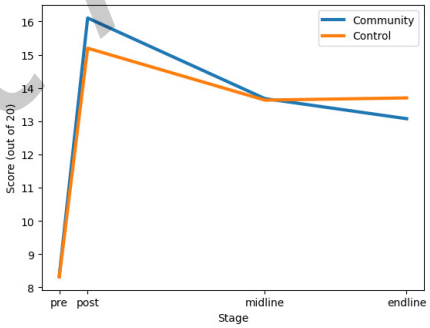

Fig. 6. Trend of questions for overall knowledge throughout the year for the two conditions across 4 data points

Figure 6 depicts the influence of time on teacher's knowledge across the year. The post-test scores show a considerable gain from the pre-test, indicating the positive effect of teacher training on improving the teacher's knowledge. After peaking at the post-test, we observe that teachers' knowledge decays across the year, as observed by the downward trend in midline and endline values. The reduction in knowledge is consistent with

prior literature, which discusses the decline of teacher pedagogical knowledge after the training. The trend is consistent across all categories of knowledge in French, Math, *NewMethod-test*, and Mentoring (as seen in Figure 8). Although teachers in the community condition learned more in the initial stages, the knowledge decay was faster in the community condition.

In the next section, we determine the impact on knowledge across two groups using difference-in-difference approach:

Table 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**	**did (%)**	**p value**
french	33.8	47.7	32.9	52.5	4.8	0.319	-1.4	0.724
math	47.3	75.0	46.2	75.0	-0.6	0.899	2.2	0.772
NewMethod-test	27.7	67.7	26.2	68.0	-0.7	0.880	9.9	0.035
mentor	55.8	75.8	57.6	80.0	-0.4	0.946	2.0	0.750
knowledge	41.2	66.5	40.7	68.9	0.8	0.786	3.2	0.361

did (%) indicates difference in differences in percentage.
p value <0.05 is considered significant, p value < 0.1 is considered marginally significant.

No significant change in *combined knowledge* over time in the community condition compared to the control condition; individual categories showed minimal changes. There was no significant change over time for *combined knowledge* in the community condition compared to the control condition. There were no significant changes in the individual categories. We observed negligible changes over time for other categories compared to the control.

In an exploratory analysis of active vs. inactive chatbot users, changes in pedagogical knowledge were observed, with significant improvements in the *NewMethod-test* component. We ran an exploratory analysis of all active vs. inactive users (A2) to understand the effect of chatbot usage on teachers' knowledge. The features for *NewMethod* knowledge in the chatbot were the same in both conditions; hence, users were divided based on their activity to understand the effect of chatbot usage on pedagogical knowledge. For overall A2 analysis, the results were not significant. Examining individual components for A2 analysis showed a significant change only for the *NewMethod-test* component. We observed a significant positive change over time for the *NewMethod-test* component (difference-in-difference: 9.9 %, p=0.035) for active users compared to inactive users. The rest of the results in A2 analysis were not significant.

Our results indicate that increased chatbot usage may improve knowledge, but solely the introduction of community features does not translate to teacher knowledge. We discuss these results further in the discussion section.

6 Discussion

We will now explore the interpretations of our results in the context of our three hypotheses related to technology adoption, teacher motivation, and teacher knowledge. We examine our interpretations within the framework of previous research in ICTD to explain the phenomenon in our data.

We hypothesized in **H1, that chatbot adoption would increase in the community, but the results were not statistically significant**. From qualitative data, we observed that teachers lost utility for some chatbot features over time, thus explaining the low difference in both conditions. Although teachers used the system, some teachers, especially in the control condition, did not see the utility in asking questions that could be obtained from the manual, indicating the redundancy of need-based features [25] over time. For example, the information from the manual, tips, and questions were targeted solely at *user needs* that, as Toyama mentioned, change over

time [101], thus reducing adoption. Unlike needs, leveraging *assets* or users' strengths paves the way for improved adoption. A prior study [27] in Côte d'Ivoire describes children's success and community as some of the core strengths or *assets* [77] in Côte d'Ivoire. Our data showed that teachers repeatedly appreciated the stories in the chatbot about children's success and appreciated connecting with other teachers. Therefore, the synergy between vCOP designs and *assets* may have improved technology adoption in the community condition.

However, external social media platforms allowed teachers in the control condition to form connections despite not having access to the features of the chatbot, leading to lowered adoption. Prior work [67] that found that internal activity in their group intervention made it hard for some teachers to participate; similarly discovered that *external systems* (WhatsApp groups) could also affect rural teachers' participation in our Facebook *DIA*. Although only one official WhatsApp group was set up by the NGO, we found that teachers organically set up groups independently. Some teachers mentioned they eventually moved to WhatsApp due to the myriad notifications and contacts they received from their colleagues. The self-motivation of the teacher community to set up and stay connected through WhatsApp groups further solidifies the importance of community for Ivorian teachers.

We found it surprising that teachers overcame financial barriers to access the community. Although Facebook was more accessible financially (due to the presence of Freebasics [4], which provided free access to Facebook and Facebook Messenger for some networks), some teachers preferred WhatsApp and were willing to pay for data to connect with their community on WhatsApp. Toyama describes self-motivation as amplification [100], i.e., when the motivation is strong, users will find pathways to navigate technological challenges to succeed at their tasks. This finding suggests that users' motivations can also help overcome financial struggles when the user is intrinsically motivated to form social connections.

We hypothesized in **H2 that motivation would increase in the community condition, and we observed an increase in some sub-scales**. The community condition, enhanced by the chatbot, showed increased professional agency and perceived colleague support, aligning with our prior work on the positive impact of community support in Côte d'Ivoire [25, 27]. For *agency combined*, i.e., teachers' professional agency in the community, there was a positive change over time for community users. We also saw a greater difference in active community users. The *professional agency in the community* scale asked questions about community support (i.e., *I ask my colleagues for support when facing exhausting work situations* or *Our teacher community can care for our pupils together*). The increase in these differences indicates the benefit of vCOP for the community condition by the chatbot. Prior work suggests that community support can be increased by a sense of encouragement [15], provided by stories in our study. Additionally, the stories helped teachers reaffirm the benefits of the *NewMethod* program for the students through the voices of other community members. Thus, the community-focused interactions may have helped reinforce existing strengths (assets [77]) in the context [27], leading to improved motivation. We observe greater differences in *perceived colleague support* in active users with a marginally significant effect (7.4 %,p=0.079), hinting at the positive change over time in the community condition towards colleague support.

However, self-efficacy experienced no significant results, potentially influenced by conflicting demands from the *NewMethod* program. Prior work has shown that teacher self-efficacy drops when there is more burnout in the context of novel teaching practices [37]. 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.

Teachers valued community-driven learning, akin to a prior peer support phenomenon [54, 109] concept documented in HCI4D literature. In community support, teachers expressed that stories from their fellow teachers helped them learn the program's importance. Prior work describes this concept as *social proof* [109], i.e., changing behavior by observing people in their circles. The benefit of community-driven behavior change

is well-documented in HCI4D work [54, 66, 73]. For example, early work in HCI4D demonstrated that farmers benefited from tips shared by peers through an interactive voice response system [73], and recent work found that Youth with HIV found it beneficial to engage and learn from their peer WhatsApp groups [54].

We hypothesized in **H3 that pedagogical knowledge will increase in the community condition, and we observed a positive change only on one knowledge 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 *NewMethod-test* and mentoring sections contained a mix of practical and theoretical knowledge. However, the questions log shows that teachers used the chatbot to ask practical questions about *NewMethod* (chatbot 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 with *NewMethod* implementation. Therefore, the discrepancy between the theoretical questionnaire and the practical questions on the chatbot may explain the results. Furthermore, teachers mentioned the discrepancy in theory and practice, which could also mean that theoretical knowledge gained would not translate into successful implementation in rural Côte d'Ivoire.

Additionally, teachers mentioned using the chatbot offline through the offline PDF manuals. We also observed increased self-reports of usage in the control region, possibly hinting at more offline usage in the control region. Therefore, offline usage in control could have helped teachers gain theoretical knowledge from the manuals and helped them do well on the pedagogical knowledge questions. The increased knowledge from offline interactions in the control may have led to reduced results in difference-in-difference for the knowledge component.

6.1 Future Work

A Case for Virtual Communities of Practice and Chatbots in Low-Infrastructure Settings: During our study, Virtual Communities of Practice (vCOPs) on social media were identified as an emerging research area with significant challenges in engaging teachers from rural areas and moderating content effectively [67, 70, 78, 105–107]. Chatbots were seen as a promising solution to these issues [41, 85, 99], though their impact in rural African contexts was uncertain. We addressed these gaps by developing a chatbot, inspired by our prior work in Côte d'Ivoire [24–26] to support a virtual community of teachers. Although preliminary, our research contributes quantitative and qualitative metrics supporting the positive effects of virtual communities on teachers' motivation and pedagogical knowledge. Therefore, future work can extend this work to create novel chat interfaces for communities. For example, an opportunity could be to work with large language models (LLMs), such as ChatGPT, to create novel interactions tailored to users' contexts, such as generating personas of mentors [72] using LLMs to help novices have early interactions with chatbots. Park et al. [72] created personas of professors to help prospective grad school applicants reflect on their future choices. The limited training requirement (such as short surveys) to make these personas in LLMs allows for the extension of these systems to low-resource contexts.

A Case for Experimental Studies Motivated by Theory in ICTD: A challenge with ICTD research is the work is too contextual, thus failing to transfer the findings to other contexts [33]. Although there have been experimental studies in ICTD [66, 82, 96, 108, 115], the work focussed on practical and contextual impact, hence transferability in ICTD research [33], i.e., translating the outcomes beyond the context of the experiment, is often challenging. Alternatively, there has been theoretical work [34, 58, 101], often hard to connect with experimental work. Our contribution attempts to bridge this gap, and we make a case for running experimental studies towards bridging the gaps between theory and practice in ICTD [22]. We have used our theoretical motivations in COPs [78, 112] and practical understanding from prior work Côte d'Ivoire [25–27] to design and conduct an experiment to understand the impact of vCOPs. We conducted a longitudinal study involving 313

teachers to assess the impact of the virtual community on teacher motivation and pedagogical knowledge. We categorized impact as technology use, pedagogical knowledge, and teacher motivation (as described by our Theory of Change, see Figure 7. To evaluate our impact, we adapted and validated existing questionnaires on perceived social support, agency within the community, burnout, and self-efficacy for the Ivorian context. Future work can use our experimental approach to extend work on emerging theory in ICTD, such as aspirations [101]. We also see the potential for chatbots and AI to play an active role in this direction due to their versatility [41, 72, 85, 99] and potential for chat-based research in healthcare [54] and education [105].

Human-AI collaboration in Low-Infrastructure Settings One notable challenge in virtual communities is the necessity for moderation [67], particularly as these systems involve teachers with low digital literacy. Our work shows a possibility to address this challenge through a humbot [26, 41] architecture, a system where human operators and artificial intelligence collaborate to answer user queries. Our work shows that the humbot architecture is suited for constrained data availability, demonstrated by the chatbot 's ability to answer questions. Since this was an experimental setup, the NGO worker re-answered queries even if the chatbot answered them. The chatbot used a static database populated from prior work in the context. Hence, it could answer only a few questions beyond a greeting. Future work can focus on building a dynamic database for that chatbot [45]. Huang et al. [45] used responses from crowd workers to automate the chatbot responses over time; this concept could be adapted to build a dynamic database, i.e., a chatbot that learns from NGO workers every new answer, further reducing the workload of the NGO worker.

6.2 Limitations

6.2.1 Low statistical power of analysis. Although we observed significant results in the Motivation category (5 and 7 significant results out of 11 variables), we acknowledge that we had low statistical power for more rigorous tests, such as error correction. In our proposed future work, we will utilize the False Discovery Rate (FDR) for exploratory error correction, adjusting p-values to q-values via the Benjamini Hochberg correction [18]. FDR controlling procedures, known to be less stringent than the Bonferroni correction when handling multiple tests [18], will be particularly relevant given the expected low statistical power in our data.

6.2.2 Challenges with implementation. 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 during the training. 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.

Another challenge 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 [57] has shown that notifications are integral to reminding users to continue using the system. Future work can consider requesting Facebook permissions that allow seven days of interaction for the human (NGO worker) interacting with the agent.

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 (vCOP) and control 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. Our analysis showed that community condition (1) improved motivation for some questionnaires, i.e., in agency in the community, and

reduced burnout over time. Our qualitative data showed that the community condition allowed teachers to learn from and support each other using the chatbot. The chatbot (2) improved pedagogical knowledge. An increased pedagogical knowledge in a category (*NewMethod-test*) was seen among active users of the chatbot. Teachers also asked questions about French and *NewMethod-test* 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. The final hypothesis is (3) increase in technology usage. The community condition showed no significant changes in average technology adoption. 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*. This study demonstrates the benefits of a virtual community of practice and conversational agent designs to support teacher professional development. Thus exposing potential opportunities for human-AI collaboration in low infrastructure settings.

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A Appendix

A.1 Theory of Change

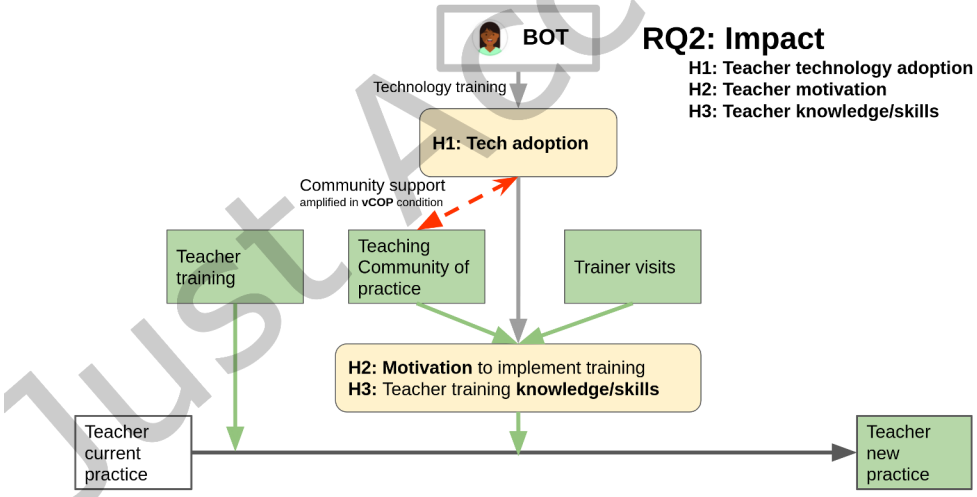

Fig. 7. Theory of change explaining impact. We categorize impact as (1) Technology adoption, (2) Teachers' motivation to implement the program, and (3) Teachers' knowledge/skills about the training. We hypothesize that active users will utilize the community features, thus leading to more motivation and knowledge.

We categorize impact as (H1) Technology adoption by the teachers, (H2) Teachers' motivation to implement the program and (H3) Teachers' knowledge (and skills) about the training. Active technology adoption would

influence teachers' motivation and impact through the community support designs. More information about the theory of change can be found in the next section.

The diagram (Figure 7) 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 teaching (*NewMethod*) method. After training, teachers are influenced by the teaching community and trainer visits. The trainer visits the teachers on a monthly basis to provide mentoring on the training, which affects teachers' knowledge and motivation. The teaching community consists of teachers in the same school and teachers in the neighbouring schools. Teachers interact with community members on official and social interactions throughout the year, influencing their knowledge (H3) and motivation (H2) on the teaching practice. Secondly, trainers visit the teachers regularly leading to new teacher practice. Lastly, active users of the training program re-share their experiences with the teaching community (community support), thus positively influencing the teacher's knowledge and motivation.

A.2 Influence of *DIA*

We introduce our chatbot (called *DIA*), a conversational agent that is designed to support teacher professional development. Our technology designs (discussed in the next section) have two versions of the system for two versions i.e. vCOP and control. Training teachers on the technology, i.e., the chatbot *DIA* will start the technology adoption for both conditions. In the vCOP condition, the community support from *DIA* will amplify [100] the community interactions among teachers, leading to increased technology adoption. The increased technology interaction among the teacher community will improve motivation and teachers' knowledge/skills.

We classify the impact into three distinct categories: (1) the adoption of technology, specifically referring to teachers adopting the chatbot; (2) the motivation of teachers for teaching; and (3) the knowledge and skills of teachers pertaining to the training program. Our hypothesis suggests that the community support provided by fellow teachers in the virtual Community of Practice (vCOP) condition will result in an increase across all three categories.

Table 8. showing different codes answered by the chatbot for 65 questions.

CODE	COUNT	PERCENT
GREETING	55	84.6
NewMethod ACTIVITY	3	4.6
DIA INFO	2	3.1
NewMethod-test INFO	2	3.1
NewMethod INFO	2	3.1
SESSION PLAN	1	1.5
TOTAL	65	

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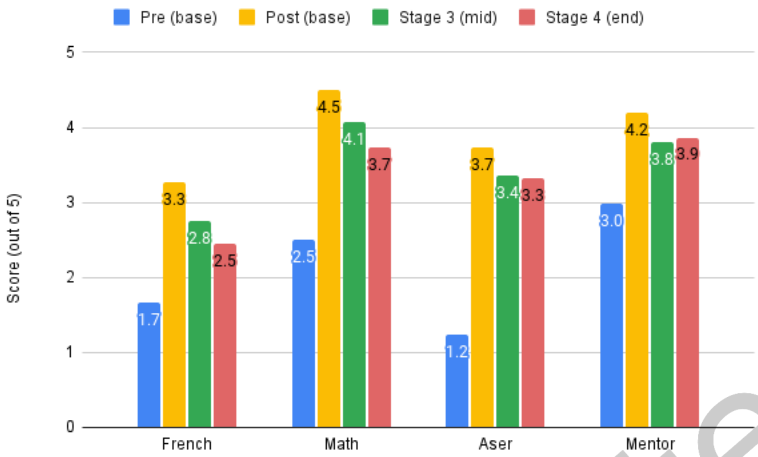

Fig. 8. Trend of questions for different components of Knowledge. See Section 5.4

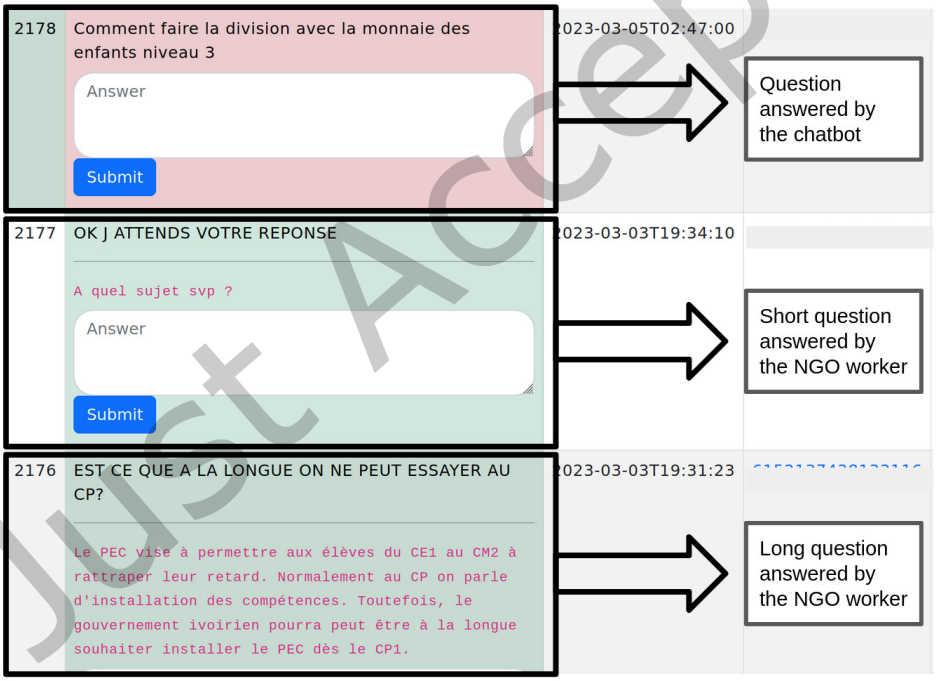

Fig. 9. The NGO workers dashboard with examples demonstrating automated and human answers

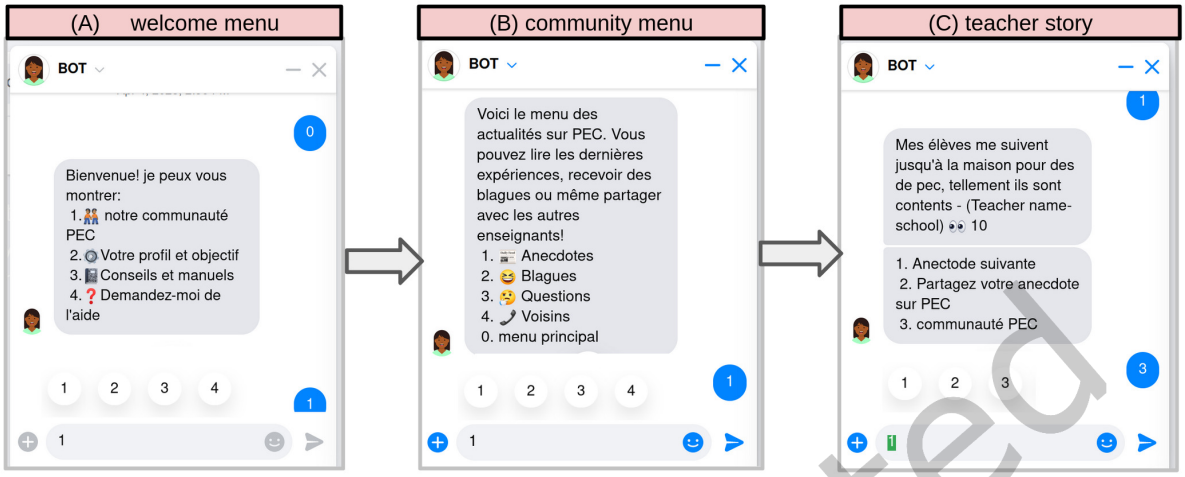

Fig. 10. A workflow of stories feature of *DIA* in the community condition. (A) User navigates to the home menu (B) User navigates to the community menu and selects stories (C) User browses a story and is provided the option to see more stories. All the menu options of the chatbot can be seen in Figure 3. If the user had access to latest Facebook Messenger, they would see buttons pop up making it easier to navigate menus.

Fig. 11. Pictures of a chatbot training session held during our study

Table 9. 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	0.800
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	0.960
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

Table 10. Baseline data categorized by questionnaires for the two conditions. This data was used for MOTIVATION([5.3]) analysis

Variable category	Question
Demography	What class are you currently teaching at this school?
Demography	In what languages do you usually teach students?
Demography	How many years of teaching experience in total do you have?
Demography	How many years of teaching experience in this school do you have?
Demography	What is your age in years?
Demography	What is your grade in teaching?
Demography	What is your highest qualification
students_info	How many children were enrolled in your class at the beginning of the year?
students_info	How many children do you currently have in your class?
students_info	How many children do you think will be able to finish the school year?
students_info	Are students used to arriving on time?
Teaching_practice	Have you been absent one day from school last week?
Teaching_practice	If you were absent from school on any day of the last week, why?
Teaching_practice	In the last school year, how often does the headteacher observed your lessons?
Teaching_practice	In the last school year, how often did a counsellor observe your lessons?
Tech_access	What type of phone do you have?
Tech_access	Which mobile operator do you have on your smartphone?
Tech_access	How many years would you say you've been using smartphones?
Tech_access	If you have a smartphone, how much did you spend last week?
Tech_access	How often do you buy a data pack on your smartphone?
Tech_access	How many days a week do you access the internet/social media?
Tech_access	Where do you have a telephone network to use the internet/media?
Tech_access	How often do you use SMS on your phone?
Tech_access	How often do you use CALLS on your phone?
Tech_access	How often do you use FACEBOOK on your phone?
Tech_access	How often do you use MESSENGER on your phone?
Tech_access	How often do you use WHATSAPP on your phone?
Tech_access	How often do you use GOOGLE SEARCH on your phone?
Tech_access	How often do you use the CAMERA on your phone?
Tech_access	Do you use Facebook Messenger?
Tech_access	What color is your Facebook Messenger icon?
Tech_access	I'm ready to use Facebook Messenger to improve my pedagogical competences

Table 11. Baseline data categorized by questionnaires for the two conditions. This data was used for MOTIVATION([5.3]) analysis

Variable category	Question
Aspirations	Why did you choose to become a teacher?
Aspirations	Was elementary school teaching your first career choice?
Aspirations	What job do you expect to have in five years?
Aspirations	Most important people approve my career?
Aspirations	Most teachers like me achieve their career goal in 5 years
Aspirations	Are you confident that you can achieve your career goal in 5 years?
Aspirations	Will you achieve your long-term career goal entirely?
Self efficacy	I am convinced that I am able to successfully teach all my students
Self efficacy	I know I can maintain a positive relationship with students, even under stress
Self efficacy	When I make great efforts, I am able to reach even the students
Self efficacy	I am convinced that over time, I will continue to become able to respond to my students' needs
Self efficacy	Even if I am disturbed during teaching, I know how to keep calm
Self efficacy	I am confident in my ability to meet the needs of my students, even though I have a bad day
Self efficacy	If I try hard enough, I know I can exert a positive influence
Self efficacy	I am convinced that I can develop creative ways to face the education system challenges
Self efficacy	I know I can motivate my students to participate in new activities
Self efficacy	I know that I can carry out new teaching activities in my
Burnout	I feel emotionally drained from my work.
Burnout	I feel used up at the end of the workday.
Burnout	I feel fatigued when I get up in the morning and have to face another day on the job.
Burnout	I can easily understand how my school children feel about things.
Burnout	I feel I treat some school children as if they were impersonal objects
Burnout	Working with people all day is really a strain on me.
Burnout	I deal very effectively with the problems of my school children.
Burnout	I feel burned out from my work.
Burnout	I feel I am positively influencing other people's lives through my work.
Burnout	I have become more cold toward people since I took this job.
Burnout	I worry that this job is hardening me emotionally.
Burnout	I feel very energetic.
Burnout	I feel frustrated by my job.
Burnout	I feel I am working too hard on my job.
Burnout	I do not really care what happens to some school children.
Burnout	Working with people directly puts too much stress on me.
Burnout	I can easily create a relaxed atmosphere with my school children.
Burnout	I feel excited after working closely with my school children.
Burnout	I have accomplished many worthwhile things in this job.
Burnout	I feel like I am at the end of my rope.
Burnout	In my work, I deal with emotional problems very calmly.
Burnout	I feel students blame me for some of their problems.
Community Agency	Other teachers' ideas inspire me to advance my own teaching.
Community Agency	I'm willing to discuss my own work with my teacher colleagues.
Community Agency	The discussions in the teacher community inspire my work.
Community Agency	I'm able to utilize the feedback from teacher colleagues in developing my teaching.
Community Agency	We are able to deal with challenging school situations together.
Community Agency	Our teacher community is able to take care of our pupils together.
Community Agency	The common development work in our school has made it easier to carry out my own teaching.
Community Agency	In our teacher community we encourage each other to develop.
Community Agency	I'm able to utilize the critical feedback I get from the teacher community.
Community Agency	I encourage my teacher colleagues to collaborate.
Community Agency	I'm willing to act in order to advance the best of our entire teacher community.
Community Agency	I can discuss even the difficult subjects in my teacher community.
Community Agency	I'm not afraid to ask the other teachers for help.
Community Agency	I'm able to support the colleagues who feel strain in their work.
Community Agency	I ask my colleagues for support when facing exhausting work situations.
Community Agency	I'm getting better and better in recognizing the situations in which I have succeeded as a teacher
Perceived social support from colleagues	There is a colleague who is around when I am in need.
Perceived social support from colleagues	There is a colleague with whom I can share my joys and sorrows.
Perceived social support from colleagues	There is a colleague in my life who cares about my feelings.
Perceived social support from colleagues	I have a colleague who is a real source of comfort to me.