How Teachers in India Reconfigure their Work Practices around a Teacher-Oriented Technology Intervention

RAMA ADITHYA VARANASI, Department of Information Science, Cornell University, USA
RENÉ F. KIZILCEC, Department of Information Science, Cornell University, USA
NICOLA DELL, Department of Information Science, the Jacobs Institute, Cornell Tech, USA

The proliferation of mobile devices around the world, combined with falling costs of hardware and Internet connectivity, have resulted in an increasing number of organizations that work to introduce educational technology interventions into low-income schools in the Global South. However, to date, most prior HCI research examining such interventions has focused on interventions that target *students*. In this paper, we expand prior literature by examining an intervention, called Meghshala, that targets *teachers* in low-income schools as its primary users. Through interviews and observations with 39 participants from 12 government schools in India, we show how the introduction of a teacher-focused technology intervention causes teachers to reconfigure their work practices, including lesson preparation, in-classroom teaching practices, bureaucratic work processes, and post-teaching feedback mechanisms. We use the concept of material agency to analyze our findings with respect to teacher agency and reconfiguration, and use theories of teacher knowledge to highlight the kinds of knowledge production that teachers in our research context tend to focus on (e.g., content knowledge). Finally, we offer design opportunities for future teacher-focused technology interventions.

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

Additional Key Words and Phrases: HCI4D; ICTD; education; teacher development; agency; reconfiguration; India

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1 INTRODUCTION

As mobile technologies become accessible and affordable within diverse communities in the Global South, a growing number of HCI researchers and practitioner organizations have been working to design and deploy technology interventions that aim to improve the quality of education in low-income schools [33, 35, 38, 51, 57, 94]. For the most part, the HCI interventions that have been studied in prior work have been designed primarily for use by *students* (e.g., [22, 38, 46, 50, 57, 94]) with teachers (sometimes) playing a supporting role in helping to deliver such interventions to students [2, 3, 47]. However, there is a need for more HCI research examining interventions that target *teachers* [4, 65] and that aim to improve teacher professionalization in the Global South. In this paper, we examine a technology intervention that specifically targets teachers as its primary

Authors' addresses: Rama Adithya Varanasi, Department of Information Science, Cornell University, New York, NY, USA; René F. Kizilcec, Department of Information Science, Cornell University, Ithaca, NY, USA; Nicola Dell, Department of Information Science, the Jacobs Institute, Cornell Tech, New York, NY, USA.

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users, and analyze how teachers in low-income government schools in India adapt and reconfigure their work practices around such a teacher-oriented technology intervention.

We ground our fieldwork in a specific case study of a teacher-focused intervention, namely Meghshala [66]. Meghshala is a non-profit educational support organization based in Bangalore, India whose main objective is to provide teachers with opportunities to improve their teaching capacity by building their pedagogical knowledge. In late 2016, Meghshala created an Android-based intervention that gives teachers access to hardware (tablets, projector, etc.), educational content for use in class, teaching strategies, and in-person support and assistance.

We conducted observations, interviews, and focus groups with 39 school faculty (teachers and principals) in 12 government schools to study how teachers respond to the introduction of such an intervention. Our findings show that teachers reconfigure multiple aspects of their work as they seek to (1) provide better learning experiences for students, and (2) simplify or reduce their own workloads, both inside and outside the classroom. We also show how the technology leads to changes in the bureaucratic processes that govern teachers work, such as how teachers are often required to prove that they are using the technology in class. Finally, we discuss how teachers reconfigure the socio-technical support structures provided as part of the intervention, adapting them in ways that expand teachers' general technical knowledge beyond the intervention.

Our paper makes the following contributions to CSCW: (1) we offer a qualitative, empirical study that analyzes how teachers in low-income schools reconfigure their everyday work practices to accommodate a technology intervention specifically designed for teachers, rather than students. This intervention is based on easily-maintained mobile phones, and accompanied by in-person support, and hence well adopted, even in low-income schools. (2) We use the concept of material agency [43, 74, 92] to analyze our empirical findings with respect to teacher agency and reconfiguration, discussing reasons why government school teachers in our study may show material agency in reconfiguring their work practices around a technology intervention when previous literature does not [4, 49, 71]. (3) We then relate our findings to current theories of teacher knowledge, highlighting the kinds of knowledge production that teachers in our research context tend to focus on (e.g., content knowledge). Finally, (4) we offer design opportunities for teacher-oriented technology interventions, including the suitability of smartphones as a vehicle for delivering teacher professional development programs, the need for interventions to support teachers' own content creation strategies, and how these interventions might simplify government schools' bureaucratic processes while reducing the administrative burden on teachers.

2 RELATED WORK

Related literature on teacher professionalization. A large body of prior work has examined teacher professionalization in Western settings. Early teacher professional development studies focused on positive cognitive traits (e.g., improving teachers' knowledge [73] or instructional practices [25, 44]). Subsequent studies sought to understand the underlying causes that led to the development of these positive traits, such as teachers' identity [41], attitudes [44], and beliefs [34]. The assumption behind these studies was that the professional development teachers' received impacted their attitudes and beliefs, which in turn impacted their cognitive traits, which then led to improved classroom performance and student outcomes [24].

A complementary line of research points out that understanding teacher professionalization also requires studying the socio-cultural complexity of the ecosystems in which teachers teach [6, 42, 77]. This approach heavily influenced understanding of technology adoption in teachers' professional development [88] because, to understand the contribution of technology in teacher professionalization, it is important to understand how such technologies become part of teachers'

every day lived experiences, and how broader school environments affect teachers' technology use [5]. Embracing these complexities, CSCL researchers (e.g., [56, 87, 99]) have studied online communities of practice and knowledge communities that encourage teachers to interact with their local context and generate constructive knowledge, which aids professional development [93, 99].

Prior studies on teacher professional development in the Global South have pointed out the socio-cultural complexities and resource constraints present in these contexts [5, 59], with a cluster of studies suggesting that many teacher-training programs in the Global South do not adequately prepare new teachers for the challenges they will face in classrooms [64, 80, 96]. Consequently, a number of technology-based teacher professionalization efforts have focused on supporting and building teacher capacities in the field, in partnership with governments [1, 11, 63, 90] and global organizations (like UNESCO) [59, 69]. For example, the DEEP project aimed to understand the impact of ICTs in teacher development efforts in sub-Saharan and North Africa [59]. The project's objective was to understand longitudinal change in thinking and practices as teachers adopted ICTs, such as mobile phones, in professional development programs in low-resource settings [59].

Our research builds on this literature by contributing a qualitative empirical study that examines how teachers in Indian government schools reconfigure their everyday work practices around a teacher-focused technology intervention that aims to build their pedagogical knowledge. We now situate our work within theoretical frameworks explaining teacher knowledge development.

Relevant theoretical frameworks explaining teacher knowledge. In the past, teacher capacity was measured on the basis of two factors: general pedagogical knowledge and understanding of the content [18]. This notion was challenged by Shulman [91], who argued that teacher capacity cannot be explained and measured in such binary terms, and who expanded the framework to include what he called *Pedagogical Content Knowledge* (PCK) [91]. According to Shulman, Pedagogical Content Knowledge includes useful forms of representations that teachers create to make subject content more comprehensible to students [91]. Such representations are carefully crafted keeping in mind the topics that are difficult for students, or those that create misconceptions. Ball [7] expanded Shulman's framework by introducing more nuanced categories of knowledge that are required to build teachers' capacity. For example, *horizon content knowledge* is an awareness of how concepts are related to other concepts in the curriculum and grades in a particular subject.

Even with such nuanced categorization within the theoretical framework, the introduction of technology brought new challenges for teaching in the classroom. Unlike other elements of teaching, technology keeps being updated on a regular basis, demanding a different treatment from the teachers to build their capacities in this regard [54]. Koehler et al. introduced technology into Shulman's PCK framework, creating the TPACK framework [55]. Central to this framework is the need for teachers to develop *technological pedagogical knowledge* (TPK), and *technological content knowledge* (TCK). For instance, TPK is the process of combining technological knowledge (TK), such as general usage of a word processing application, with pedagogical knowledge (PK), such as the concept of critical thinking. TPK brings those elements together – for example, using Google docs to hold a critical thinking discussion about a particular topic. The TPACK framework considers the amorphous nature of technology and encourages teachers to adopt technology to improve their content and pedagogical capacities while avoiding technocentric approaches. [89].

Nevertheless, many technology interventions in HCI have taken technocentric approaches. Famous interventions, such as hole in the wall [67], OLPC [2, 3, 21], Los Angeles Unified School District (LAUSD) [22], and the FATIH program [50] are some of the programs that have not provided teachers with a central role (completely or partially) in the deployment of their technology interventions. With the failure of many technology-deterministic initiatives, a major criticism of HCI studies has been how these initiatives view teachers as passive actors and disregard their teaching

practices when designing interventions. Considering these challenges, there is a need to shift from technocentric approaches towards creating technology-enhanced education environments that place teachers at the center of the intervention, and provide strong support and capacity building for teachers, leading to more meaningful integration of technology in classrooms [40].

Related literature on teacher agency. Recognition and understanding of agency as a critical component of teachers' work processes occurred in the latter part of 20th century, when research around teacher thinking materialized as an important line of study [19]. Teacher agency is defined via three important teacher characteristics [18]. First, their capacity to affect change on various stakeholders in the school ecosystem, including its ecology [75]. Second, the existence of teachers' awareness that they brought about such change, including change in others' learning. Third, teachers' awareness of their own influence and power to handle institutional and community-based challenges. It is therefore possible to look at the teacher agency from a few different perspectives. Studies have also looked at the process of constructing self-efficacy, defined as teachers' conviction to affect contextual pedagogical tasks, such as providing support to students and management of classroom, at a certain quality in the classroom environments [23]. Another way that studies have shaped the meaning of agency is from the perspective of teachers' autonomy to act in classroom and school settings [29, 82]. It is important to note that autonomy in the context of teachers is not just expression of individual self, independent of external factors (e.g., authority, community, and peers). Instead, it is a delicate balance between individual freedom and external constraints [18].

One way that teacher agency has been previously explored in teacher development literature is through understanding narratives of teachers' lives in the context of their experiences around personal, social, and professional aspects of life across time, place, and relationships [62, 84, 95]. Work on teacher agency has also been explored in the field of teacher research to understand how it not only impacts various teacher work activities, such as preparation [12, 76], teaching [10, 61], and community interaction [78, 85], but also with respect to technology, such as technology usage in classrooms [30] or involving teachers in technology design and integration [13, 53]. Teacher agency in this sense, relates to a characteristic that is always developing in relation to the technology and the ecosystem rather than being a fixed capability [5, 75]. There is also a considerable amount of research that has explored teacher agency in developing countries [28, 58, 97]. Our study expands this literature with an empirical study in Indian schools that examines teachers' agency, via reconfigurations, with the introduction of teacher-focused technology interventions. In doing so, we show how teachers are active agents in these socio-technical contexts [17].

3 RESEARCH METHODS

The goal of our work is to study how teachers in low-income government schools in India reconfigure their work practices to accommodate the introduction of a technology intervention that specifically targets teachers, rather than students. We ground our analysis in the context of one specific teacher-focused intervention: Meghshala [66]. We provide some background on Meghshala before describing a four-month qualitative study with teachers in government schools in 2018.

3.1 Meghshala: Case Study of an Educational Technology Intervention

Meghshala is a non-profit educational support organization based in Bangalore, India. Meghshala's main objective is to provide teachers with opportunities to improve their teaching capacity by building their pedagogical knowledge. In partnership with Karnataka state government, Meghshala currently supports teachers in over 130 schools and, at the time of writing, has initiated collaborations with three more Indian states by expanding their contextualized app content. We engaged with Meghshala in a research collaboration in which we studied their intervention closely, in both urban

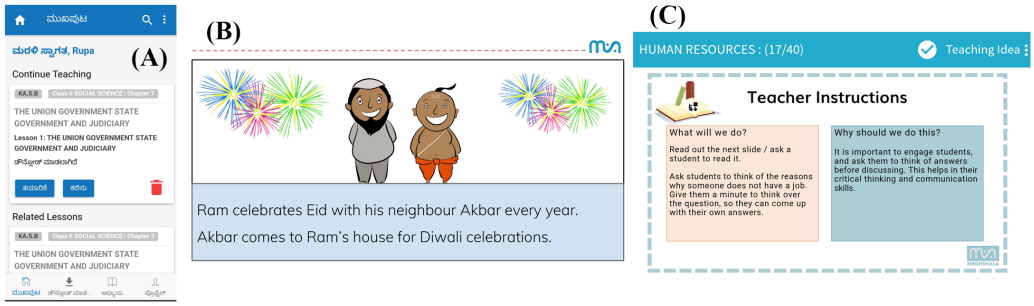

Fig. 1. (A) Screenshot of Meghshala's app showing available TeachKits; (B) Example of a Meghshala content page; (C) Example of a Meghshala preparation page.

and rural government schools in India. Before beginning our research in schools, we spent several weeks in Meghshala's headquarters in Bangalore, talking with their team members, observing their work, and attending meetings, with the goal of understanding their content development process, deployment strategies, and high-level vision.

To achieve their objective, Meghshala provides an app-based intervention that is delivered to teachers via an Android device (see Fig. 1). In some cases, Meghshala provides the hardware (tablet, pico projector, portable wifi router) needed to deploy its intervention, usually two to six Android tablets per school. Schools are not expected to return the hardware after usage or if they discontinue the intervention. In other schools, Meghshala does not provide any hardware and teachers are instead expected to use Meghshala's app on their personal devices. The app is also available on the Android PlayStore, so anyone can download and install the app on their device.

To use terminology coined by Collins & Moonen [20], Meghshala's app can be considered a *core technology* in the sense that the tool is the principal way in which Meghshala provides support and learning for teachers in classroom environments by assisting teachers with the preparation and delivery of classroom lessons. The content that the app provides consists of modules that have been developed by Meghshala's team and that are carefully contextualized to the curriculum and pedagogical philosophy of the state government's educational board while also incorporating new ideas and practices to build the teacher's capacity. To achieve this, Meghshala incorporates the 5E's inquiry-based model (engage, explore, explain, elaborate, evaluate) on which the state government curriculum is based. Each chapter in the state-prescribed textbook is mapped to multiple Meghshala modules, called *TeachKits* in the app (see Fig. 1A). Each TeachKit consists of two types of pages (similar to PowerPoint slides): *content pages* that teachers can show to students in the classroom, and *preparation pages* that guide the teacher to deliver the lesson effectively (see Fig. 1B and 1C). The idea is for the teacher to prepare for class using the preparation pages and teach the content using the content pages. At the end of each TeachKit, teachers have an option to provide feedback on the content around several criteria using star-rating system.

Finally, in addition to the app, teachers also receive on-the-ground support from Meghshala's personnel, who visit schools regularly to help with technological, content, or pedagogical queries. We chose Meghshala as the focus for our study because its teacher-oriented technology intervention combined with its in-person, on-the-ground support made it an ideal case study for our research.

3.2 Field study with teachers in low-income schools

After spending several weeks in Meghshala's offices learning about their intervention, we conducted fieldwork with teachers in 12 low-income, non-English medium government schools, in both rural and semi-urban contexts. These schools began using Meghshala's intervention in mid-2016.

Recruitment and Participants. We recruited a total of 39 school faculty (33 teachers, 6 principals) for our study. Schools were chosen in partnership with Meghshala and based on a number of criteria. Specifically, we wanted schools in both rural and semi-urban areas who had been using Meghshala for at least 1.5 years. We also wanted a mix of schools who received different intervention variations (e.g., both with and without hardware provided), received varying levels of in-person support, and with varying levels of adoption of the intervention. Based on these criteria, we worked with Meghshala to reach out to candidate schools, seeking their permission to conduct research.

After receiving formal permission from the schools, we recruited participants via word-of-mouth and school WhatsApp groups. Participants' demographic characteristics are provided in Table 1. All participants spoke the local language (Kannada) and several also spoke Hindi (one of the official languages of India). Teachers were also able to understand conversations in English.

Qualitative Methods. In total, we conducted 32 semi-structured interviews, 12 focus groups, and observed 22 teachers as they went about their work. Since we were introduced to participants by Meghshala, we took care to explain that we were *not* affiliated with the organization, but were independent university researchers. Nevertheless, participants may have perceived us as being associated with Meghshala, leading to possible bias that we discuss in Section 6. Interviews lasted between 30 minutes and two hours. In six interviews, other curious teachers voluntarily joined the interview discussion, leading to spontaneous focus group sessions. When this happened, we counted these interviews as a focus group. Our questions sought an understanding of teachers' work practices, with and without Meghshala, as well as experience with technology interventions more broadly. We situated our questions in our participants' daily work practices as a teacher, both inside and outside the classroom. Interviews were audio-recorded and conducted in Hindi or Kannada, depending on the participant's preference. In addition to the interviews, we also observed teachers as they went about their daily work, including their preparation process, teaching in the classroom, administrative work and conversations in staff room, and so on. Observations typically lasted 15-45 minutes, during which we took detailed notes and photographs (with permission).

Data Collection and Analysis. We collected 86 hours of observation data via detailed notes and photographs and 43 hours of audio-recorded interview and focus group data. The recordings were translated into English when necessary and transcribed. We analyzed the transcripts thematically [8] using Atlas.ti software, starting with a close reading of the data in which we allowed themes to emerge. Multiple passes over the data resulted in a codebook that consisted of 61 codes (e.g., trusting students with tech, juggle between apps/blackboard/textbook, cherry picking content). These codes were then clustered into themes (e.g., bureaucratic processes, social support structures, and searching for content) that represent our main findings discussed below.

In addition to our qualitative data, we also obtained all of Meghshala's app usage logs for the year 2017-18. The data consisted of 9 million unique instances of teachers' Meghshala usage. An instance is recorded when a teacher uses a TeachKit for more than five seconds. The app records the time spent using the TeachKit, along with the page number, type of page (preparation vs. content), and TeachKit details (name, grade). This dataset was cleaned before being analyzed using R.

Participants	Teachers: 33; Principals: 6	Gender	Female: 25; Male: 14
Age (years)	Min: 25-30; Max: 45-50; Avg: 35-40	Locality	Semi-urban: 22; Rural: 17
Experience (years)	Min: 2; Max: 30; Avg: 12.7; St.D: 6.6	No. of subjects taught	Min: 1; Max: 3; Avg: 2

Table 1. Teachers' Demographic Details.

4 FINDINGS

Our findings show how teachers in government schools in India work to reconfigure and renegotiate multiple aspects of their work to accommodate the introduction of a teacher-focused technology intervention: Meghshala. We structure our discussion of these reconfigurations around different phases of teachers' work lives: preparation and lesson planning, classroom teaching and activities, bureaucratic or administrative processes, and other socio-technical support structures.

4.1 Reconfiguration of teaching preparation practices

Outside of classroom settings, a major work activity that teachers engage in is preparation and planning for classes. Our participants explained how their preparation processes primarily involve two activities: (a) preparation of teaching learning materials (TLMs) that can assist them in teaching their classes, and (b) preparation of formal lesson plans that they submit for approval to the school's leadership. We now discuss these in turn.

Reconfiguring Teaching Learning Materials (TLMs). TLMs are used as aids for teaching in the classroom. Common TLMs include preparing chart materials for conceptual explanations, building 3D models using scrap materials, kits for science experiments, videos to help students understand a concept, in-class activity materials, and more (see Fig. 2A). Participants (n=32) described to us how, since the introduction of Meghshala, they are able to include content from Meghshala as TLMs in their classes. They believed that this reduces the amount of time needed to prepare lessons, since they no longer need to create TLMs from scratch or search online to find content that is culturally appropriate, in the relevant language, and suitable for the grade and subject they teach.

Building on this belief of being able to save time, teachers described how they used this extra time to try and find other resources that are more culturally and contextually appropriate for their students. Including such content makes it easier for teachers to discuss potentially advanced concepts in ways that are easier for students to understand. These findings tie into previous studies that examine teachers' ability to materialize newly formed beliefs as an essential component of their development. Such studies have emphasized the critical role of teachers' beliefs in defining teaching tasks in the classroom [32, 34]. By showing how teachers translate their new beliefs into reconfigurations of their work practices, we build on studies that emphasize how real-time teaching practices change in classroom contexts, instead of beliefs [5, 39].

In some cases, Meghshala's platform provides content that has been highly contextualized to the Indian context (see Fig. 1). However, teachers felt that their ideas for content to include were often more appropriate than the content provided by the platform. For example, P10 discussed how he included a YouTube video as a TLM because of its stronger cultural and contextual fit with his students compared to Meghshala's resource. He said,

> *"I had to recently teach a topic in Social Science around the great king - 'Chitradurgada'. Even though Meghshala has relevant content on, I felt it was not enough for students to understand the topic clearly. I searched on YouTube to find a video song, acted by a famous movie actor Vishnuvardhan. This video song covers everything about the king and his*

history. Children can immediately relate to it video like these ... Meghshala does not have similar video." - Teacher 10

In a similar vein, our participants discussed how they often included content relevant for the subject and grade they are teaching that they received via teacher WhatsApp groups. Several participants preferred this channel for receiving content since the content is often already tailored to their specific teaching needs and syllabus. For instance, P02 (an English teacher) compared her experiences receiving information via WhatsApp with a general online search experience. She discussed how she was looking for definitions for new vocabulary, but when she tried to search on Google, the results she got were highly generalized. However, when she reached out on her teacher WhatsApp group, she received the exact list she was looking for already curated by a teacher from another school. This finding builds on literature discussing communities of learners [9, 86] by showing how WhatsApp groups have motivated teachers, who may be otherwise isolated, to establish networks that build a community of learners, as well as develop school knowledge with their colleagues by obtaining resources and orchestrating administrative tasks [59].

Another key finding that participants discussed was how the content provided by Meghshala sometimes gave them new explanations for specific concepts that they were previously unaware of. Using Meghshala's content as TLMs enabled these participants to think about different ways of teaching the textbook content. For instance, P30 remembered her excitement when seeing the Meghshala resource that explained how to extract honey from bees, which included a video from a local neighborhood. She recalled her decision to use it in class after she realized that she was not aware of certain steps in the extraction process and felt that it would be a really valuable video to include while teaching. Similarly, P37, explains her experience teaching the concept of triangles,

"In the Triangles topic, earlier we used to teach the basics...what's present in the book. For example, what is triangle, it's properties, etc. However, in Meghshala, there are various examples of how Triangles are used in the construction of bridges and shape of triangles is really effective in doing this. We ourselves [referring to his colleagues in the room] never knew that triangles could be applied to these kinds of practical applications. I showed this to students and I could tell that the students found it very useful to understand triangles better" - Teacher 37

Prior work in Bangladesh [90] and Africa [59] have also found teachers making connections between ICT-based content and gaps in their content knowledge. We extend this literature by also showing the importance of the contextual relevance of content provided by the application [5].

The ways in which teachers use Meghshala content as TLMs for their classes contrasts with the ways the organization intended their platform to be used. Recall from Section 3.1 that Meghshala's TeachKit includes content pages, with contextualized materials for concepts in the curriculum, and preparation pages, that are intended to provide ideas for how teachers can teach these concepts in their classes (see Fig. 1). Our analysis of Meghshala's usage data showed that teachers spent only 11% of their overall Meghshala usage time on the preparation pages.

Reconfiguring lesson plans. In addition to preparing TLMs for their own use, teachers also have to go through the bureaucratic process of formally creating and submitting lesson plans for approval by the principal. The structure of these lesson plans is set by the respective state government. In our study, all teachers used consistent government-mandated structures for their lesson plans that is based on the 5E's inquiry-based model [72] (see Fig. 2B for an example of one such lesson plan for a Math class on the topic of integers).

However, participants (n=21) reported that when organizations introduce new initiatives, the teachers are given opportunities to modify their lesson plan structure in ways that might conform to the objectives of the organizations. For example, Meghshala's objective is to help teachers improve

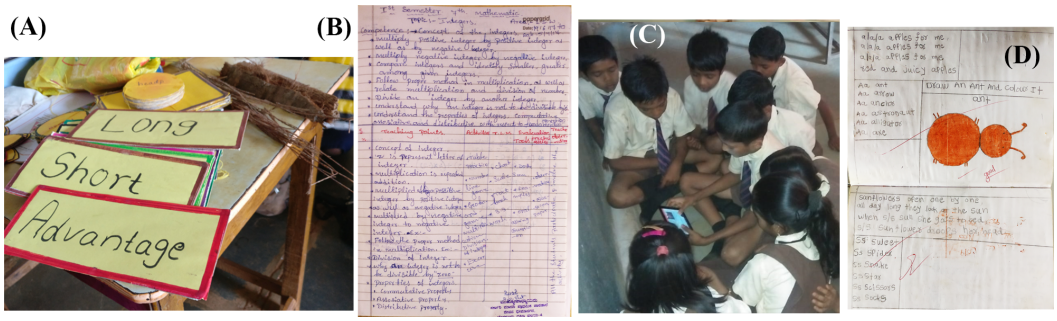

Fig. 2. (A) Traditional TLMS for English vocabulary; (B) Example of a teacher's lesson plan; (C) Combining Meghshala with textbook-based teaching while encouraging student-centered technology exploration; (D) Example of a student's Meghshala workbook.

their teaching by using Meghshala's app as a primary preparation and teaching tool. As a result, teachers are given opportunities to include Meghshala-based resources in their lesson preparation and teaching. It is mandatory for teachers' formal lesson plans to include a list of specific TLMs they plan to use before they can get approval. To include Meghshala content in a lesson plan as a TLM, our participants discussed how they would write down the specific TeachKit and discuss with the principal the specific slides they intended to use. As P22 said,

> *"Whenever a teacher brings their lesson plan for an approval signature to me, they will inform me and mention that, "I want to use particular pages of Meghshala" or " I want to do these Meghshala activities." . . . In the lesson plan, they mention correspondingly what part of Meghshala they used." - Teacher 22 (Principal)*

4.2 Reconfiguration of classroom teaching practices

Having explored how teachers reconfigured their preparation and lesson planning activities, we now examine how teachers' shifted their in-classroom work practices to accommodate the intervention. Teachers in government schools in India are typically required to cover vast amounts of syllabus over relatively short periods of time. For example, several participants discussed how they are required to complete an entire textbook in one semester, with students taking exams on that syllabus at the end of the semester. Thus, teachers told us that completing the syllabus is their primary objective. Meghshala's intention is for their TeachKits to replace textbook-based teaching. Instead of teaching from the textbooks, the TeachKits provide lessons that Meghshala wants the teachers to use end-to-end rather than using the corresponding textbook chapters. However, our findings show that teachers neither follow a strictly traditional approach (utilizing only the textbook) nor do they follow the new approach intended by Meghshala (using only the TeachKits). Instead, for a variety of reasons that we discuss, they create new, hybrid approaches to teaching that mix and match content and strategies from all of the mediums that are available to them.

Reconfiguring content delivery. Several teachers discussed how they strive to achieve a balance between incorporating more engaging Meghshala content and timely completion of the syllabus for traditional exams. As one teacher described,

> *"We select what is important whether we are conducting normal [textbook-based] class or through Meghshala. If we don't have much time, we only teach normal class, even if Meghshala is effective. If there is time and opportunity in revision, we cover specific elements from Meghshala. If we cover lessons from Meghshala, then there is a risk of*

> *falling short of syllabus completion. For example, if I don't finish all the classes before 4pm, I can't let them play games or sing in lower class." - Teacher 04*

This quote is a good example of the kinds of critical reflections on Meghshala voiced by teachers in our study. Teachers' desire for shorter, more focused Meghshala content that can quickly and easily augment the textbook-based syllabus is corroborated by our analysis of Meghshala's usage data. When we analyze the frequency that Meghshala's TeachKits are used end-to-end (i.e., the number of times each TeachKit was opened and used end to end), we see that usage decreases as TeachKit length increases (see Fig. 3C). On several occasions, teachers (n=8) mentioned instances where they deliberately ignored good content available in Meghshala simply because they did not have the time to use it in class due to the need to complete the syllabus. Other participants (n=12) also described how they ignored content in Meghshala if it digressed too far from the textbook. These findings connect to Christin's study [16] on reconfiguration, which discusses instances of open critique (similar to the previous quote from teacher 04) by legal professionals and journalists adopting new technologies. Similar to how teachers resist using Meghshala since it prevents them from completing the syllabus, journalists in Christin's study resisted the use of new analytic software because they felt excessive focus on click metrics might push them to compromise on article quality. Our work then goes further by showing how teachers' critical opinions resulted in new workarounds as teachers try to balance Meghshala content with textbook content.

One reason to include Meghshala content in their teaching was to overcome a lack of classroom resources. Most of the schools we worked in did not have much more than a small collection of books that constituted a makeshift library. Using content provided by Meghshala provided teachers with easier ways to explain complex concepts from the textbook. We observed how teachers would frequently project Meghshala content (e.g., animated simulations of a science experiment) on a wall of the classroom while explaining the concept to students. For analytical subjects like Math, teachers often preferred to combine content projection of Meghshala with the blackboard. We observed instances where teachers projected Meghshala content on one portion of blackboard to either interact with the digital content by drawing over the projected area or to augment the digital content by writing on a different portion of the blackboard. As P25 explained,

> *"In Maths, we frequently project Meghshala concepts on that side [of the blackboard]. [On this] side we use the black-board to solve [problems] and show the steps. Otherwise, children cannot pick up the concepts quickly." - Teacher 25*

Beyond projecting content, teachers also reconfigured their in-class activities based on Meghshala. In some cases, teachers learned an activity from Meghshala and then recreated it for students in their classroom to help explain more abstract concepts. P04 explains one such instance,

> *"There was one activity in the Earth chapter of Meghshala . . . that showed how the big bang occurred. In that activity, a balloon is blown up and something is put inside. By bursting the balloon, I showed how the big bang happens like that . . . It was wonderful. Students understood well." - Teacher 04*

Several participants went even further to integrate new strategies they learned through Meghshala with their traditional teaching processes. In subjects like science and social studies, we observed how teachers combined traditional textbook activities with Meghshala content. For example, two participants (P01, P06) brought different types of flowers to the classroom to demonstrate the parts of a flower and their reproduction processes, which they combined with Meghshala's content on the same topic. The teachers then spent time discussing the connection between the live example in hand (textbook activity) and the content provided on the device (Meghshala activity). These mindful reconfigurations, where teachers chose to use only specific technology features appropriate for the task at hand, are evidence of *technology-in-practice*, an important aspect of digital materiality

as defined by Orlikowski [60, 70]. Such examples of reconfigurations in the context of digital materiality have been explored in other domains, such as digital infrastructures [36, 37].

Reconfiguring student group work and individual exploration. Beyond teacher-led content delivery and activities, we also found that teachers worked to incorporate technology into students' group work in the classroom. Recall that Meghshala often provides several (two to six) tablets to schools they partner with. We observed how teachers would arrange to use any of the devices that were available. Then, they divided the students into groups and gave each group a tablet (see Fig. 2C) that displayed the relevant content or activity, while they also used one device to project content for the room. The teachers said that facilitating hands-on student interactions with the tablets was an easy way to ensure students' *"undivided attention."* In several cases, we even observed teachers passing their own personal smartphones to groups of students while they continued teaching the concept (see Fig. 3A). In addition to group work providing students with opportunities for independent exploration, teachers also described how they helped some students who wanted to be able to explore more on their own. As one teacher described,

> *"Earlier, when we showed videos on YouTube, students used to go home, search, and watch the videos to learn from that. Now that we shifted to Meghshala, they keep asking us how to download the app so that they can explore themselves." - Teacher 37*

Teachers said they often dedicated some of their personal time to teaching their students how to download and install the app on their parents' phone at home.

We also discovered that many teachers (n=12) have created new roles and responsibilities for students to help maintain and care for the hardware (tablet/smartphone, projector, dongle). Specifically, teachers assigned certain students to be 'Meghshala leaders', whose responsibilities included assembling hardware for class, ensuring devices were charged, making sure that the hardware is packed up and kept in its assigned location, etc. These roles rotated on regular basis among all students. In addition to teaching students about leadership and responsibility, the teachers described how these practices saved considerable time when they used Meghshala in class.

4.3 Reconfiguration of bureaucratic work processes

In addition to reconfigurations in teaching practices (inside and outside the classroom), our findings also reveal new bureaucratic processes set up by the school's management as a result of the technology intervention. One such bureaucratic process is a requirement that teachers be able to prove they use the intervention, and failing to do so could get them into trouble. A participant said,

> *"Before this, on one occasion [a government official] came and checked. We could have showed all the records. But there were no Meghshala records. He came and asked "Did you do Meghshala class?" The teachers replied that they did take the class. He asked them to show the record but there was none. He wrote a report indicating that they were not using Meghshala." - Meghshala Personnel*

To meet this requirement of proving engagement with Meghshala, our participants said that they now maintained paper-based documentation, such as written logs of Meghshala activity, so that they could show the school's management or visiting government officials that they were using the technology. For example, several teachers created a new feedback register (see Fig. 3B) to record their students' feedback that, beyond proving their detailed and consistent use of Meghshala, could also be used to provide feedback to Meghshala's on-the-ground support personnel. Such feedback is the teachers' way of supplementing the basic star-rating feedback system provided by the app.

As another example, several teachers have their students maintain a Meghshala workbook that is only used for Meghshala related activities (see Fig. 2D). These workbooks provide a paper trail that

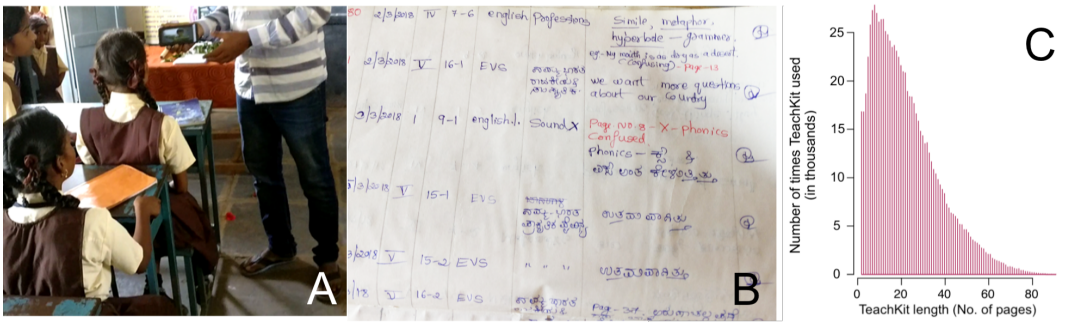

Fig. 3. (A) Teacher showing Meghshala content to students; (B) Example of a Meghshala feedback register; (C) End-to-end usage of Meghshala TeachKits of different lengths (usage decreases as length increases).

proves teachers' regular usage of Meghshala to higher officials. These findings are an example of what Espenland & Sauder [31] call *gaming*—manipulating the rules in ways that are unconnected to their original purpose. Christin [16] also explores this phenomenon in her work, describing how journalists use clickbait strategies to distort and boost article popularity, while legal professionals intentionally redirect cases to circumnavigate problematic ones. In ICTD contexts, Radjou et al. [79] use the term *jugaad* to refer to "ingenious ways to game the system", providing an example of how millions of Indians use missed calls to communicate while avoiding text message charges.

In addition to proving Meghshala usage to higher management, the Meghshala notebook also served to prove to students' parents, who are mostly from low-income communities, that their children were learning and using technology. A number of teachers described how their schools were seen by the community as being old-fashioned, with teachers relying on old techniques (i.e., textbooks). Participants felt that this perception was especially true in schools, like theirs, that were non-English medium schools, since many parents wanted their children to learn English. As Meghshala contains English content and helps the teachers to teach English, proving that the students were using Meghshala helped to combat negative perceptions. One teacher said,

> *"Meghshala's app is very useful for English. Because our school is a Kannada (non-English) medium government school, we have to teach English a lot better. All parents want their children to learn English and insist that we teach English … That is why I depend more on Meghshala as it is really useful for teaching English." - Teacher 11*

Our participants also described how they often did not play a large role in determining which technology interventions would be deployed in their schools or how they would be introduced. For instance, Meghshala personnel described how they formed partnerships at the block level (a block comprises multiple clusters of schools) or higher. Thus, technology is often introduced via top-down approaches instead of involving teachers in the planning stages to encourage adoption. Moreover, most of our participants said that they had been a part of at least three prior technology-oriented support interventions in the last five years. As one participant said,

> *"We were using another intervention program before Meghshala. After Meghshala came, we have forgotten how to use that intervention because now we use Meghshala. Sometimes, we feel as if we are in a queue. If some support organization discontinues its support, another organization comes in its place. There is always a next organization in the queue. Naturally, we are not finding time to show the old software now. We are now depending on Meghshala." - Teacher 12, Principal.*

4.4 Reconfiguration of Socio-Technical Support Structures

As mentioned previously, part of Meghshala's intervention involves sending on-the-ground support staff to the schools they partner with to assist teachers with any challenges they encounter when using Meghshala, including hardware set-up, general troubleshooting, or pedagogical and content challenges. Our analysis shows how these interactions are negotiated in several ways.

First, we discovered that teachers' interactions with Meghshala's support people often led to teachers learning and using new technologies that are beyond Meghshala's intervention. For example, several teachers (n=12) mentioned how they used their newly developed understanding of castable apps (learned from Meghshala's support people) to browse other castable apps on the PlayStore that are related to their subjects. In particular, P25 mentioned how she found a castable app to show 3D model of human anatomy to explain topics like internal organs or the digestive system. P25 discussed at length how difficult it is to find topics that have a casting option. She said,

> *"Through Meghshala's support person, we came to know about this new tool called Meracast (a low-cost casting device) and how to cast using it. Then we tried to find various apps on different curriculum topics like digestion, solar system, human body, etc. If we are in the digestive system lesson, we download an appropriate castable app and we can directly show it on the screen. We can't do that for all of them. For example, there is an app called solar system that is not supported [by these devices]. We have to test which ones are supported"- Teacher 25*

As another example, several teachers discussed how they had learned to use a tool called ShareIt (a mobile app that transfers files by creating a local WiFi network, without the need for Internet) to transfer content to the castable tablet from their personal smartphones. Further, P04 mentioned how she had learned the process of taking screenshots on her smartphone from the Meghshala support person and then used the technique later to provide screenshots of a Meghshala lesson to a peer when the Meghshala TeachKit was not working on her peer's phone.

Beyond learning and using new technologies, we discovered how teachers strive to be active contributors in the creation and improvement of Meghshala's content. For example, our participants often spent significant amounts of time in meetings with Meghshala support people to provide critical feedback and ideas for how to better fit Meghshala content to the teachers' needs. For instance, P35 showed us how he sent specific suggestions with examples about types of local videos that could be added to Meghshala to help teachers in his community prepare graphs in maths. P35 sent his suggestions to the Meghshala support person over WhatsApp. Another teacher described,

> *"One suggestion that we gave was to add a section for different small budget ideas for the teaching learning materials for the lesson that we can use. If there can be a section on how the teaching aid should be made it will be really helpful. For example, there is a lighthouse chapter, we have made a lighthouse model with children, we have made it with a small battery." - Teacher 19*

Similarly, the feedback register mentioned above that some teachers maintained contained the TeachKit taught, date and time, and detailed feedback on the content, along with any mistakes in the TeachKit. These comments included suggestions for how the content could be improved to fit the teachers' contexts better. A few teachers used WhatsApp groups to report feedback, often providing a screenshot of the content that needs improvement. Even though Meghshala has a feedback (star rating) system at the end of each TeachKit, the teachers in our study developed their own techniques for providing more in-depth feedback as they strove to conceptualize how their feedback might be translated to actionable items. Similar teacher inclinations towards sharing ideas and knowledge have been well studied in communities of practice [98], professional learning communities [27, 93], and within broader communities where teachers live and work [59].

Finally, since Meghshala's support people travel to many schools, they share stories of challenges and issues at one school with others. Thus, the support people act as *information pollinators*, sharing solutions with other teachers facing similar challenges. For example, one Meghshala support person mentioned how she saw one teacher use a digital app to make phonics cards to help students with pronunciation. She found the card-making process useful and related to teachers' struggles in other schools. Thus, she shared this idea with teachers at other schools when she visited them to provide support. By acting as pollinators, Meghshala support people help to create loose and informal teacher networks [48, 96] that support indirect interactions between teachers [52]. However, unlike the strong teacher network characteristics depicted by Rincon [83], which include establishing new connections with other teachers, building trust and accountability via such newly formed connections, and improving one's teaching practices through collaborative inquiry, Meghshala-formed networks rely explicitly on the participation of the support people.

5 DISCUSSION

Our findings show how teachers in Indian government schools reconfigure their work practices in innovative ways to accommodate a new technology intervention that targets teachers as its primary users. We now discuss these findings in the context of prior work on teacher agency and reconfiguration. We then relate our findings to theoretical frameworks of teacher knowledge. Finally, we offer design opportunities for teacher-focused technology interventions.

5.1 Agency, reconfiguration, and teaching in HCI4D

Putting agency into context. We use the concept of *material agency* as developed in Science and Technology Studies by Haraway [43], Pickering [74], and Suchman [92] to analyze our findings with respect to teacher agency and reconfiguration. A central argument underlying these prior studies is that agency as an attribute does not reside in either the humans or the non-human entities. Instead, agency is an outcome, achieved as a result of specific configurations between humans and technologies. Pickering [74] built this arugment by situating *material agency* as being temporally emergent in users' practices rather than a fixed trait in either users or tools.

In our study, material agency emerged when teachers during the preparation processes realized that they could save time by using Meghshala as a TLM instead of spending large unnecessarily large chunks of time and resources in preparing traditional TLMs. Teachers acted agentically by reconfiguring their work practices to save time and instead leverage it in ways that improved their classroom teaching experiences (i.e., finding more contextualized content to make their explanations easier). Such material agency (i.e. saving time during preparation) did not exist in teachers' (human entity) prior practices and was also not a direct objective of Meghshala's (non-human entity) design. In organizational studies, a similar argument is made around material agency by differentiating technological artifact from the user's *technology-in-practice* [60, 70]. Although Meghshala's app has many usable features (technological artifact), the specific practice of substituting it in the place of traditional TLMs (technology-in-practice) to save their valuable time represents material agency.

We further deepen the relevance of material agency in our work by connecting it with the relevant literature on teacher professional development. In our study, we find that material agency for teachers cannot exist in isolation. Rather, there is a bi-directional association between material agency and the ecological context in which agency is enacted [5]. For instance, we saw how top-down school requirements pushed teachers to shape their material agency by reconfiguring their work practices so that they were able to adopt Meghshala in their former teachers teaching practices. On the other hand, opportunity utilized by teachers to customize their lesson plans requires higher management to re-consider the criteria for what they consider as an *acceptable* lesson plan.

Therefore, when teachers submit their diverse lesson plans, principals needs to constantly mould their idea of a good lesson plan.

We also see how teachers' reconfigurations extend prior work on epistemological autonomy [18] in the direction of material agency. Maclellan [18] describes epistemological autonomy as teachers' capability to foresee and make informed decisions based on situations that challenge their overall teaching processes. In our study, we saw how teachers estimated challenges in their students' understanding of the default textbook material and therefore sought more culturally and contextually relevant content for their classes using Meghshala, YouTube, and WhatsApp (through their peers). Such content allowed teachers to improve the conceptual understanding of their students. A similar level of autonomy is shown when teachers recognize and take advantage of opportunities to modify and experiment with their lesson plans. Likewise, teachers show autonomy in their decisions to create feedback registers and Meghshala workbooks (reconfiguration by *gaming*) while foreseeing challenges around bureaucratic processes and satisfy them.

In addition, teachers used reconfiguration by *open critique* [16] to combine new technologies (e.g., Meghshala) with their knowledge of traditional teaching methods, mixing and matching content from a variety of different mediums to improve learning opportunities for students. These strategies provide insights into teachers' self-efficacy in executing context-specific instructions [23]. Taken together, the idea that teachers can consciously effect change (self-efficacy), combined with the capability to make informed decision about the contexts that influence their teaching (autonomy), enabled teachers in our study to gravitate towards making decision that allowed them to be more agentic in their work. We now discuss these agentic processes within broader HCI4D contexts.

Situating teachers' material agency in HCI4D. We are aware that our study paints teachers in Indian government schools in a relatively positive light and want to acknowledge that not every teacher in low-income government schools will demonstrate agency or be motivated to do new and creative things with their lessons. Teachers in these contexts face a wide range of challenges, including low pay, infrastructure challenges, frequent transfers, student absenteeism, etc. [81] and many teachers justifiably seek to minimize their workload. We believe that there are several reasons why teachers in our study show material agency in reconfiguring their work practices around a technology intervention when previous literature (e.g., [4, 49, 71]) does not.

The introduction of a relatively open-ended technology intervention (flexible adoption), with buy-in from school leadership, within an otherwise rigid top-down school system provides room for teachers to experiment with different kinds of reconfigurations (discussed above) to make their work easier and better. For example, teachers tried to find a middle ground between tackling rigid and top-down objectives (e.g. syllabus completion) and effective student-centered teaching. While teachers deliberately skipped good content on Meghshala to complete their syllabus, they found innovative ways to integrate technology content with traditional mediums (e.g. the blackboard).

Another reason that teachers demonstrate material agency in our study is because they are motivated to improve how the local community perceives teachers. To achieve this, teachers used structures that they created (e.g., Meghshala workbooks) to show students' parents that their children were learning and using technology. Similarly, teachers taught students how to install educational apps used in class on their parents' phones, which may also let parents know that the teachers were incorporating technology into their classrooms.

These findings contribute a better understanding of the agentic practices that teachers in HCI4D settings employ while striving to balance the external constraints they face against their individual freedom to act in such constrained situations [15]. Understanding this balance will enable HCI4D practitioners and researchers to build teacher-focused interventions that do not ignore teachers' primary objectives set by top-down structures (e.g. syllabus completion).

5.2 Connecting to theoretical frameworks of teacher knowledge

We now discuss what our study reveals with respect to theoretical frameworks of teacher knowledge. Findings in Section 4.1 show that teachers use Meghshala as a preparation tool to make their lesson plans more flexible and to reconfigure TLMs. However, usage data from Meghshala revealed that teachers' preparation time is unequally spent on content pages, with only 11% of time spent on preparation pages. Moreover, teachers also explicitly discussed how they use Meghshala to improve their content awareness in class. Based on this, we surmise that, as they reconfigure their work practices, teachers gravitate towards developing their Content Knowledge (CK) more than their Pedagogical Knowledge (PK). One reason for teachers' preferences for developing CK may be the push from higher management for them to focus on syllabus completion, or a lack of resources in government schools to help them learn how to teach complex concepts and experiments.

In addition, teachers also showed a preference for developing their content knowledge even outside of Meghshala, using tools such as WhatsApp and YouTube. For example, there were instances where teachers frequently requested contextualized content for their classes from their peers via WhatsApp. Ball et al. [7] categorized such behavior as development in *knowledge of content and students* (KCS), combining knowledge of the content and knowledge of students' needs in the class. We found in our study that teachers have a good sense of understanding about their students' knowledge levels. By reconfiguring their work practices to include contextualized content that students can easily understand, teachers improved their KCS, which is an important component in developing teachers' Pedagogical Content Knowledge [7, 91].

Moreover, in technology-rich ecosystems, in addition to Pedagogical Knowledge (PK) and Content Knowledge (CK), Technology Knowledge (TK) is also necessary for teachers to develop their understanding of more complex interactions in PCK [54]. Teachers in our study showed multiple instances where they developed their TK to effectively deliver CK in their classes. For instance, we showed how teachers developed their understanding of castable apps through Meghshala's on-the-ground support staff. In addition, teachers repurposed this newly developed TK to extend and improve their teaching of various complex concepts via technology. This process of repurposing their newly learned technology knowledge to improve content explanation (and not the other way around) indicates development of teachers' Technological Content Knowledge [14].

5.3 Design implications for teacher-focused technology interventions

Smartphones as a platform for teacher professional development programs. Our findings suggest that Meghshala is a reasonably well-functioning technology intervention that has seen good adoption within government schools in India, an achievement that is relatively rare in the HCI4D literature. Our analysis points towards a number of ecological factors incorporated into Meghshala's intervention that could be emulated by designers or practitioners creating future teacher-focused technology interventions. In addition to being based on easily-maintained mobile phones that teachers are familiar with, the intervention provides contextualized content, a range of implementation strategies (e.g. providing chargeable and portable projectors and tablets), in-person support, engagement with state government, and buy-in from school leadership. These factors all contribute to an environment that supports teacher professionalization, and we saw teachers integrating student-centered teaching into their traditional teaching processes, developing new orchestrations around the technology, and establishing teacher networks over WhatsApp to build communities of learners. Such agentic practices, where the technology recedes into the background, becoming a simple tool that extends teachers' daily lived experiences [5, 45], provide evidence that smartphone-based tools, with mindful implementation, can be a useful vehicle for the delivery of teacher professionalization programs in the Global South.

As an example, one potentially fruitful path forward is to leverage widely-adopted social networking platforms as the basis for new teacher professionalization programs. Our findings show that teachers already use WhatsApp to communicate with other teachers and share content. In our next study, we plan to leverage these already existing networks to provide teachers with directed mentorship on different aspects of professionalization (e.g., self-reflection, pedagogy, classroom management). The asynchronous nature of WhatsApp interactions may make it feasible for teachers to find time to understand the concepts, contextualize them to their own classroom settings, reflect, and share their experiences. Combining such digital mentorship programs with periodic in-person support might be one way to improve teacher professionalization in the Global South.

Support teachers' content creation strategies. Our analysis also suggests design opportunities for content knowledge tools like Meghshala. We found that teachers often want to share and contribute relevant content that they personally curated (via WhatsApp, online) or created, but currently have no way to do so within Meghshala's intervention. This suggests an opportunity to create a space within Meghshala's app where teachers could upload, save, and curate their own content. In addition to using such content in their own lessons, teachers could share content they find useful with Meghshala or their peers, which enable the development of grassroots teaching content and also support teachers' desire to contribute to the intervention.

Develop data-driven techniques to simplify bureaucratic processes. Our analysis also reveals opportunities for the designers of teacher-focused interventions like Meghshala to help schools ensure accountability while reducing the administrative burden on teachers. For instance, in our study, teachers needed to create new structures (feedback registers and Meghshala workbooks) to prove to school management that they were using Meghshala. However, Meghshala is already collecting usage data, including times and dates of when each TeachKit was used, and could provide this data to school leadership, perhaps through a visualization dashboard or app. Beyond simply documenting Meghshala usage, there are numerous future opportunities for organizations to deliver data-driven insights that may be useful for teachers and higher management. These opportunities are not dissimilar to those seen in community health programs in HCI4D contexts, where technology organizations such as CommCare [26] or Medic Mobile [68] provide tools (e.g., dashboards) for frontline workers, program managers, and supervisors.

6 LIMITATIONS AND CONCLUSION

This paper described a qualitative analysis of how teachers in government schools in India reconfigure their work practices to accommodate a technology intervention that specifically focuses on teachers as the primary users. We discussed how these reconfigurations demonstrate teachers' strong sense of agency and desire to be active contributors to such interventions, rather than passive consumers of technologies that have been designed for them. We also related our findings to current theories of teacher knowledge, highlighting the kinds of knowledge production that teachers in our research tend to focus on, in addition to revealing important gaps in teachers' knowledge base that are yet to be filled. Finally, we offered design opportunities for researchers and practitioners interested in developing teacher-focused interventions.

We acknowledge that our findings are based on a specific case study of one teacher-focused technology intervention: Meghshala. Thus, there is a possibility that some of our findings are specific to Meghshala, although we believe that many aspects of our work will be applicable to other, similar, such interventions. Also, since we partnered with Meghshala in our study, it is possible that we obtained a more positive view of the intervention than we might have if we were not associated with the organization. Our study was also conducted in a specific country (India) and context (government schools), and the schools we worked in may not be representative of all

Indian government schools. Future work will be necessary to understand how our findings may generalize to other countries and contexts.

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