Educational Content Creation and Sharing by Low-Income Visually Impaired People in India

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ABSTRACT

Low-income visually impaired people face a wide variety of educational challenges which are magnified in the developing world. Digital assistive technologies (such as screen readers) are typically out of reach, so individuals depend on Braille and audio recordings to access educational content. Unfortunately, there are acute shortages of Braille and high quality audio books for many subjects, leaving students scrambling for ways to continue their education. We present a formative study that examines the educational landscape for low-income visually impaired communities in rural and peri-urban India, the challenges they face in accessing educational content, and the solutions they have invented. We conducted interviews with 16 stakeholders, including students, teachers, and content producers, to understand the education ecosystem in their communities and how they use technologies such as basic mobile phones to consume, create, and share educational content. In particular, we found that these communities have established an informal network of peer-produced audio content that is shared via Bluetooth, memory cards and CDs. Our analysis suggests ways in which technology can improve access to professionally authored materials and augment these informal networks of peer-production.

Categories and Subject Descriptors

H.5.m. [**Information Interfaces and Presentation**]: Miscellaneous

Keywords

Visually impaired; blind people; education; mobile; ICT4D; HCI4D; India; developing countries

1. INTRODUCTION

The ratification of the United Nations Convention on the Rights of Persons with Disabilities guarantees, among other fundamental rights, "the right of persons with disabilities to education" [1]. Although this treaty has been signed by 158 nations, there is still limited availability of educational materials in accessible formats for visually impaired people in the developing world. While people in the developed world often use Braille or digital educational content, 90% of the world's 285 million visually impaired live in developing countries, where it is difficult to obtain these materials. Limited availability of Braille printers and affordable, local-language digital assistive technologies (AT) means that accessible educational content is out of reach for the majority of low-income visually impaired people living in rural and peri-urban areas. These barriers to accessing educational content severely impede low-income visually impaired communities in exercising their right to education.

Our goal in this paper is to understand the challenges faced by rural, low-income visually impaired communities in accessing educational content, including their current solutions and coping mechanisms, and to apply that knowledge towards designing new or improved tools/processes for supporting the educational ecosystem. To this end, we conducted 16 qualitative interviews of diverse visually impaired stakeholders including students, recent dropouts and graduates, teachers, and an independent producer of educational content for the visually impaired community. We interviewed low-income visually impaired students from hard-to-access rural and peri-urban areas to better understand the challenges faced by marginalized people among the visually impaired community in India. Most of the students who participated in our study are from families of farmers, daily wage laborers, and shopkeepers.

All participants reported an acute shortage of accessible educational content. Participants reported a significant decline in the availability of Braille books after 8th standard, and although the availability of audio books is much higher than Braille, most of the content for undergraduate courses, graduate courses, and competitive examinations is still unavailable in any accessible format. To meet this need, an informal, self-sustaining ecosystem of user-generated content and peer-to-peer sharing has organically blossomed. Mobile phones play a critical role in empowering these low-income visually impaired communities to produce, access and disseminate audio educational content.

The ecosystem of content creation and sharing uncovered in this paper is unique in several ways. Though prior research has documented peer-to-peer media sharing practices among low-income sighted people [22, 43], this is the first study to report on content creation and sharing by low-income visually impaired people. The ecosystem is further distinguished by its focus on educational content, its roots in rural and peri-urban areas, the reliance on a portfolio of low-cost technologies (spanning CD players and basic mobile phones), and the amount of content that is produced by users themselves as opposed to being pirated or professionally curated. This paper contributes a characterization of this socio-technical system, an analysis of its strengths and weaknesses, and a set of recommendations for how technologists and policy makers can improve access to assistive technologies and educational content for low-

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income visually impaired communities in India. In particular, we recommend creating an accessible central repository that indexes the available Braille and audio content. We also advocate authoring mobile applications that facilitates easier mobile media sharing, flexible audio playback and efficient content authoring.

2. RELATED WORK

People with disabilities often have higher unemployment rates or are not engaged in the labor force at all [7]. However, both access to higher education [49] and use of assistive technologies [35,45] have been shown to improve occupational and financial outcomes for people with disabilities. In the developed world, visually impaired people access textual information through Braille books [39], audio recordings [29], or screenreaders on their phones or computers [26, 30].

Many of these assistive technologies are poorly suited for the developing world due to physical and financial constraints. While Braille and audio recordings do not require expensive devices to use, the cost of production and distribution for both formats is quite high [29, 36]. Screen readers require a computer/smartphone, a robust screen reader program, and an Internet connection which are beyond the reach of the majority of the low-income visually impaired people in the developing world [36]. Even when the technological requirements for screen readers are fulfilled, the limited availability of inexpensive TTS for Indian languages further limits the adoption of screen reader software by visually impaired people who are not fluent in English [5, 46]. While previous research has explored the usage of screen readers in India, study participants were typically highly educated and recruited from urban areas [25, 35], and were not representative of visually impaired people in rural and peri-urban areas. Though researchers have provided general recommendations for designing low-cost AT for people suffering from visual impairment in India [36], the recommendations do not offer ways to improve the creation, consumption, and sharing ecosystem for educational content.

When assistive technologies are too expensive or cumbersome to use, disabled stakeholders often appropriate general-purpose devices to serve as assistive devices. Hurst and Tobias have found that personalization, passion, and cost have driven disabled individuals to make their own AT or to adapt existing technologies for their use. They have argued that custom-built AT is less expensive, works better than the existing solutions, and results in higher adoption rates [17]. People with motor and visual impairments reported choosing commodity cell phones rather than devices specialized for people with disabilities, due to the high cost of those devices [20]. Dawe found that families of children with cognitive disabilities would often purchase simple devices intended for non-disabled users (such as voice memo recorders) due to their simplicity and the ease with which they could be replaced if broken [10]. While these interview studies show that general purpose devices have been adopted for personal use by people with disabilities, they do not examine the use of these devices to access educational content.

Researchers have also documented rich media sharing practices among low-income, low-literate sighted people where they found that users share both popular media, such as pirated movies and songs [23], as well as self-created media like folk music from local areas [22]. This media can be shared via memory cards [22], CDs, DVDs, and memory sticks [13], or even researcher-created portals for sharing multimedia content [13, 24]. These low-income, low-literate people often must overcome significant user interface barriers in order to share mobile media content and to satiate their entertainment needs [43]. However, none of these studies have examined the sharing of educational content, and while participants may have struggled with interfaces, they did not face the same barriers to access that disabled users must overcome.

Researchers have also studied the adoption of mobile phones by sighted children in rural India for accessing educational content when they were given access to mobile phones for 26 weeks [21]. However, the children accessed educational content by playing mobile learning games rather than by authoring or sharing it. Moreover, this study is an examination of an outside intervention rather than an existing ecosystem.

Though regulations and policy recommendations exist to improve access to education in India, they are currently hampered due to a lack of funding and human resources [16]. Until these recommendations can be put into practice, we must gain an understanding of the methods visually impaired people currently use to access education materials in order to support and improve them. To the best of our knowledge, our work is the first qualitative study of low-income visually impaired people in rural and peri-urban areas of India to understand the holistic education landscape and the challenges faced by them in accessing AT tools. We are also the first to report on a self-sustaining ecosystem of user generated educational content and peer-to-peer content sharing by the visually impaired community.

3. STUDY DESIGN

To better understand the challenges faced by low-income visually impaired people while accessing educational content, we conducted in-depth qualitative interviews of visually impaired people. We used purposive sampling [37] to select participants for the study who satisfied the following inclusion criteria:

- Must be visually impaired.
- Must be either:
  - A teacher from a rural or peri-urban area.
  - A student (or recent student) from a low-income family in a rural or peri-urban area.
  - A content producer for visually impaired people.

The objective of interviewing current students, recent graduates, and recent dropouts is to understand how the educational landscape has changed in the recent past for visually impaired people. In addition, it is also important to understand the challenges faced by visually impaired adults who completed their education before the era of mobile phones. This information helped us to understand the role that other digital technologies like tape recorders, cassette players, CD players, etc. have played in their lives and how this reliance is impacted by the adoption of mobile phones. Thus, we have also interviewed visually impaired people who are now employed as teachers in rural areas. There are several social, technical and financial constraints while authoring content for visually impaired people. For better understanding of these challenges, we have also interviewed visually impaired people who are authoring audio content for visually impaired people.

In July 2013, we launched an Interactive Voice Response (IVR) service, *Sangeet Swara*, that provided a voice-based social media platform for low-income, low-literate communities in India. The platform saw large adoption from visually impaired people. While analyzing the usage of the platform, we asked all active users to take an IVR survey wherein they were requested to share background information with us. Of the 161 respondents of the survey, 42 voluntarily disclosed that they suffer from some form of visual

impairment. Since there was a sizeable visually impaired population from rural and peri-urban areas on our IVR platform, we used this system to recruit participants for our interviews. While this approach offers direct access to rural users, one implication is that all participants were already engaged with an IVR system to curate, access, and share user generated content among themselves. Though these participants are from low-income families in rural India, it is conceivable that they are more advanced mobile phone users than their peers.

We conducted semi-structured telephonic interviews of visually impaired students of various educational levels (N=7), recent dropouts and graduates (N=3), and visually impaired teachers (N=5). All interviewed visually impaired teachers teach sighted kids in rural and peri-urban areas. We also interviewed a visually impaired content producer (N=1) who works as a teacher during the day and single-handedly produces professional quality educational audio content for visually impaired people during the night time. Four participants reported that the content producer is very popular among visually impaired people in North India and is regarded as a community champion because of his large scale independent efforts.

We asked several open ended questions from participants to understand their challenges in accessing educational content, and opportunities for technologists and policy makers to alleviate these challenges. The questionnaire was mostly similar for students, teachers, recent dropouts, and recent graduates. However, the questions asked to content creators were different, focusing more on the motivations behind their efforts and challenges they faced in creating high quality content.

All the interviews were conducted in Hindi by the first author, who is a native Hindi speaker. Each interview lasted around 50 minutes. The responses from participants were recorded, translated and transcribed. We reviewed and analyzed each interview immediately after conducting it. The observations that emerged from data analysis informed interview questions for the next participant. We continued to recruit participants until no new observation emerged after performing review and data analysis. Other researchers have also reported that new themes emerge infrequently after the analysis of twelve qualitative interviews [14].

In addition to conducting the interviews, we analyzed the services offered by six nationwide government entities, non-profit organizations and non-governmental organizations (NGOs) generating educational content for visually impaired communities. The analysis was conducted on the information present on their website. We also conducted telephonic inquiries when relevant information was absent from the websites. We analyzed various services offered by these entities like schemes to improve education for visually impaired people, educational content produced in Braille format and audio format, costs associated with accessing educational services, and mechanisms to enable on-demand content creation.

3.1 Participants Demographic Information

A total of sixteen participants were interviewed. All were native Hindi speakers. Some spoke a local dialect of Hindi and one participant was a fluent English speaker. Fifteen participants were male and one was female (only one self-identified visually impaired woman answered the survey on our IVR service). Fifteen participants were completely blind and one was partially blind with 30% visibility. Ten participants were blind since birth and the remaining lost vision at the age of 2, 4, 5, 7, 8, and 10. None of these six participants used a computer before they lost vision. As the IVR service was prevalent in North India, participants were recruited from four states in northern India: Madhya Pradesh (N=7), Rajasthan (N=5), Haryana (N=2), and Delhi (N=2).

Among current students, one was a middle-school student (7th standard), three were high school students, two were pursuing bachelor's degrees and one was enrolled in a master's program. Both recent graduates had finished their bachelor's and were unemployed. One person dropped out of middle school and was a blind cricket player[1] at the time of the interview. All five teachers were employed in schools for sighted students. The community champion we interviewed works as a teacher during the day and moonlights as an independent producer of educational content for the visually impaired community.

Nine participants had never used a computer. Seven participants reported using a computer at least once in their lifetime. The majority of participants were basic phone or feature phone users. Three participants had a low-end Nokia smartphone which costs less than USD 150[2].

The students, recent graduates and dropouts were from low-income families of farmers, daily wage laborers and shopkeepers in rural areas with median annual family income of USD 1000 . The median annual family income for teachers was USD 5500. The average age of students, recent graduates and dropouts was 21.9 years (min=15 years, max=32 years, median=21 years). The average age of teachers was 36 years (min=29 years, max=42 years, median=39.5 years).

4. ANALYSIS

We used open coding for analyzing the data obtained from qualitative interviews. We identified eight broad themes that inform the education ecosystem for visually impaired people and then aggregated these eight themes into three categories related to content consumption, content sharing, and content creation using axial coding [44].

4.1 Content Consumption Practices

Dominance of Audio Books over Braille Books

Due to the shortage of Braille content, all participants struggled to get Braille books. Visually impaired students are required to study from Braille books through standard 8, but from standard 9 onward, students are encouraged to explore other accessible mediums such as audio books. Once students leave high school, it becomes significantly harder to access Braille material. College students (and recently-graduated participants) complained about the extremely low availability of Braille books for their courses. Moreover, few Braille books are available for competitive examinations that must be passed to secure a reasonable job in India.

The shortage of Braille books is compensated by high but fragmented availability of audio books (also known as talking books). Audio books are easily available from 9th standard till 12th standard for every subject except Mathematics and Sanskrit. However, the availability of professionally produced audio books is also scarce for post-secondary courses. Though the comparative availability of professionally produced audio books is significantly higher than the Braille books, a great deal of educational content is still unavailable in either format. Many participants applauded the structure and ease of use of professionally authored educational content in audio format.

> *I use a mobile phone to listen to educational CDs. Just as a director provides 6 songs in a movie and all are recorded by different artists, here there are audio clips*

[1] `http://en.wikipedia.org/wiki/Blind_cricket`

[2] In this paper, we use an exchange rate of 1 USD = INR 60

for introduction, conclusion, question and answers for chapters, etc. For example, for science, there are clips for every experiment and practical exercise. These audio clips are part of a CD and you can play them in your mobile phone or CD player.

P5 (Male, Student, Class 11)

Content Consumption Devices

Many participants reported storing educational audio content in the memory card of their mobile phone for convenient access to study material. Of course, mobile phones were used for far more than just listening to audio books; participants reported a wide range of other educational uses for their mobiles. These included obvious things, such as calling classmates or teachers to ask questions. But they also included less obvious things such as:

- Accessing online content using mobile screen reading software
- Recording notes and important questions in class or at home
- Recording reading sessions by a sighted person
- Recording remarks by an instructor

These days, mobile phones with memory cards are available. We dump the study material in the memory card so that we can listen to it whenever we want to. If we don't understand a question, we ask our friends using the mobile phone. The government is also running a program - Grameen Shaikshainik Shikha - through which we can call a number, 1800117372, to ask questions. The answers to the questions are provided in 48 hours.

P4 (Male, Student, Class 10)

I record songs, poems, notes and books. I used to stop my lecturer for a minute and ask him to repeat what he said, in order to record the most important stuff.

P8 (Male, Finished Bachelor's, Unemployed)

To better understand the devices used for consumption of educational audio content, we asked our participants to list all the devices they use to listen to audio books. Participants reported using mobile phones (N=9), computers (N=4), CD players (N=4), and tape recorders (N=4).

Participants preferred mobile phones because mobiles are battery powered, and thus robust to the intermittent availability of electricity. Moreover, phones also offer ubiquitous availability of audio content. Several participants also found mobile phones to be easier to use than other devices. Tape recorders were mostly used as a legacy technology to play old collections of audio books. The main benefit of laptops was the large storage capacity which is useful for storing audio books. We found that mobile phones were popular among young audiences and CD players were popular among middle aged participants. The majority of students, graduates, and recent dropouts (median age=21) reported that the mobile phone was their preferred content consumption device, while the majority of teachers (median age=39.5) preferred the CD player or tape recorder.

Though some smartphones and feature phones support reverse and forward operations, most low-end phones do not support these operations. Some participants preferred CDs and tape recorders over mobile phones because these devices often have better options for seeking and playing content.

I listen to content on a tape recorder or CD player. I don't listen to it on mobile. This is because if we want to rewind on mobile, the whole audio file is rewound and played from the start. In the case of CDs or cassettes, you can rewind just a bit as well.

P14 (Male, Teacher)

Preferred Content Format: Braille or Audio?

Braille books come with a wide range of limitations: they are hard to come by, expensive, heavy, and require a good deal of physical storage space. However, despite these limitations, all but two participants preferred Braille over audio books. In general, participants indicated that reading Braille helps them better understand and remember content. In addition, they liked the fact that Braille allows them to control their reading speed and Braille books do not depend on electricity. Even though they tended to prefer Braille to audio books, all participants appreciated the wider availability and lower cost of audio books.

Audio books are a compromise. The joy of reading on your own is inexplicable. Audio books are just a way to get things done because it is difficult to have a collection of Braille books.

P14 (Male, Teacher)

Personally, I prefer Braille. Because when you read it yourself, you understand it better. In the case of audio, you have to listen to it again and again. Moreover, the quality of audio books is dependent on the reader.

P6(Male, Student, Bachelor's)

Finally, skill in reading Braille represents a certain independence that participants aspired to. The community champion, popular for generating educational audio content, also preferred Braille books over audio books:

Personally, I am a supporter of Braille. Braille is the real thing. There are two things: first, eating food yourself. Second, someone else feeds you. Braille is like eating food from your own hands and audio books are as if someone else is feeding you.

P11(Male, Community Champion)

Limited Access to Screen Readers

Nine of the sixteen participants stated that they had never used screen reader software to access digital content on computers or phones in audio or Braille formats and three of these had never heard of screen reader software and didn't know its purpose. Among the seven participants who reported using screen reader software, three participants reported using it on both a computer and a phone, one only on a computer and two used it exclusively on a phone. We did not have data for one person. Five of the seven screen reader users were students and two were teachers. Nokia Screen Reader and pirated version of Nuance Talks were popular among phone users of screen reader software.

Many study participants complained about the language of audio output used in the screen reader software. As the language of instruction for all participants was Hindi, some of them reported having difficulty understanding the accent of a screen reader that outputs audio in English. They either have to listen to the output a couple of times, or ask someone for help which completely defeats the purpose of screen reader:

I don't have good English. So, I have to listen 2-3 times to whatever the talking software says. If I get stuck somewhere, I have to ask someone for help.

P13 (Male, Teacher)

Although some Indian languages could technically be supported by a few robust screen reader programs like JAWS, the cost of those screen readers is prohibitive for low-income visually impaired people. In most cases, the output of inexpensive local language speech synthesizers is of poor quality, and thus results in very little use. Moreover, the educational material for teaching languages themselves (Hindi, Sanskrit, Kannada, etc.) is difficult to use with the existing screen reader software:

My subject is Hindi. That is why I cannot use JAWS (screen reader software). I have to use recorded material.

P10 (Male, Student, Master's)

4.2 Content Sharing Practices

Peer to Peer Sharing of Audio Content

In response to the shortage of educational content in either Braille or audio format, visually impaired students and teachers have evolved rich peer-to-peer sharing practices for educational content. Indeed, all participants reported sharing educational audio content. Participants reported that the easiest and fastest way to access any educational audio content is to ask whether their friends or teachers have it.

Participants reported sharing audio books by using Bluetooth (N=4), sharing CDs (N=6) and by exchanging memory cards (N=6). Many visually impaired participants initiate Bluetooth sharing by memorizing the complex steps of button presses and user interface navigation. This echoes other research demonstrating that low-income low-literate people can overcome significant barriers in user interface to access interesting content [43].

We share the books but only with trusted people. We generally give a memory card or CD. Sometimes if a chapter or two is missing, we send it via Bluetooth. I know how to use Bluetooth on some mobile phones, not on all. I remember the sequence of keys that I have to press.

P4 (Male, Student, Class 10)

One participant also reported sharing content by playing it from her device. This kind of intermediated access to technology and content for low-income communities in the developing world has also been shown elsewhere [42]. Here, intermediated access to content is particularly helpful for those visually impaired people who either don't own a playback device, or who own a phone without an external memory card or Bluetooth.

4.3 Content Generation Practices

Industrial Production of Audio Books

While visually impaired students and teachers are eager to share the content that they have, there is still a critical shortage of Braille books or professionally recorded audio books. Governmental organizations such as the National Institute for the Visually Handicapped [33], and NGOs like Arushi [4], All India Confederation of the Blind [2], Saksham [41], the National Association for the Blind [31], and the National Federation of the Blind [32] produce high quality educational material for visually impaired communities. However, a careful inspection of the list of books available in Braille and audio format from these organizations indicates a good deal of duplication of some books and large gaps in other areas. Thus, the availability of content is quite fragmented and major portions of educational material are still unavailable in any accessible format.

Participants also reported reaching out to these organizations to get high quality audio books for competitive examinations, courses, magazines, novels, etc. An audio book consisting of multiple CDs can be easily obtained by paying USD 0.1-0.5 per CD. Some of these organizations also provide a service where people can send a printed book to them for conversion into an audio book. They then produce a high quality audio version for the book, archive it and send it to the requester. Though the cost for the service is quite low (less than USD 5), participants have to wait for months to access the audio version of the book.

We go to Sakhsam and they ask us what material do you want, for what course, etc. They check whether they have it in their computers or not. If they have it, they give the material in a CD. They charge 5 Rs (USD 0.1) per CD. If they don't have a book and if you can wait for the book to be converted to audio, you can give the book to them and they give the audio version in 2-4 months.

P10 (Male, Student, Master's)

You can also get your material recorded by NGOs but I have never tried this long process. It takes a lot of time and there are many organizational issues. They have membership fees, and we have to pay charges. For an unemployed person, even 50 Rs (USD 0.8) is a big amount. Hence, I take the material from my friends.

P8 (Male, Finished Bachelor's, Unemployed)

A few organizations such as Civil Services Audio Notes [40] provide access to high quality audio notes for some competitive examinations. Visually impaired people can either buy offline content sold in a memory card or stream the content online. However, the cost of accessing the content, both in online and offline mode, is around USD 40 which is beyond the reach of low-income visually impaired people.

Content Generation by Community Champions

Many participants also reported reaching out to community champions who record, archive, share and distribute educational audio books in their free time. The popularity of these community champions spans multiple geographic regions; participants from different states pointed us to the same set of community champions. We interviewed one of these community champions who had recorded audio books for courses and competitive examinations for four of our participants.

The community champion we interviewed is a full time teacher in a school for sighted students. In his spare time, he hires a reader to convert a popular monthly general knowledge book (*Pratiyogita Darpan*[3]) into audio format. This book is helpful in preparing for competitive examinations. Visually impaired people get the audio version of the general knowledge book by paying a modest annual membership fee of USD 2. At the time of writing, the service has

[3] `http://emagazine.pdgroup.in/`

more than 75 members in 10 states of India. The community champion also provides a service where visually impaired people can send him empty CDs and books (for sighted people) to get a high quality audio version. Thus far, he has produced more than 100 audio books for school courses, college courses, and competitive examinations for MBA entrance, banking jobs, administrative services, and teaching positions. All the books are stored in his laptop and whenever there is a request for already produced content, he writes a CD and send it to the requester. In the last 3 years, more than 500 students have benefited from his volunteer efforts.

The community champion reported several challenges in creating high quality audio books. He found it particularly challenging to create audio version of books for Mathematics because he found equations and other technical terms difficult to understand in spoken form. Another challenge is to make the effort economically sustainable. Because he caters to low-income visually impaired people, book conversion services are free and visually impaired people are charged only for receiving an audio CD. Currently, the cost of labor and material is sponsored by the Rotary Club.

The champion accentuated the need to use the Digital Accessible Information System (DAISY) standard [9] for creating high quality audio books so that the content is well structured and searchable. Moreover, DAISY format allows users to place bookmarks and regulate the playback speed.

> *We use a software that records in the DAISY format. The normal CD has a capacity of 700 MB. It can contain only 150 songs. That is 450 minutes of recording. The software that records in DAISY format enables us to record up to 50 hours of recording. Pratiyogita Darpan [general knowledge book] takes 17-20 hours of recording. Hindi subject guide for 2nd grade teacher [for teachers who teach middle school students in India] takes 75 hours and thus it takes 2 CDs.*
>
> P11(Male, Community Champion)

User Generated Audio Books

Even given the services provided by professional organizations and volunteer community members, a great deal of educational content remains unavailable in any accessible form in a timely fashion. Visually impaired communities have responded to this by individually or collaboratively producing their own audio content.

Many visually impaired people purchase books (written for a sighted audience) and then ask a friend, family member, or anyone who is willing, to record it for them. Sometimes they are approached by social workers or others who may record the books themselves or have them recorded by a third party. Participants reported that user generated content is so abundant that it is not uncommon to see two people in the same class accessing an audio book recorded by two different people for the same content.

> *We ask people to record the books. We ask anyone who is ready to record. We ask an educated person who has good pronunciation. We give them a book and CD, and compensate them for their efforts.*
>
> P6 (Male, Student, Bachelor's)

Many participants reported hiring a reader to record or recite course content for them. A reader is either hired by a group of visually impaired students or by an individual. Participants preferred to create a group and then split the cost of a reader among group members. There are no fixed norms or wages for paying a reader. Some participants paid readers per hour while others reported paying per book. Participants reported paying anywhere between USD 0.5 per hour to USD 2 per hour. It is also a common practice by visually impaired people to record the reading sessions themselves using a mobile phone, laptop or a tape recorder. Many participants shared the process of generating content:

> *I get my material recorded from students if they can read good Hindi. Sometimes I also take help of teachers, friends and some social workers. Generally people do it for free. But sometimes I pay those who are economically struggling so as to make it mutually beneficial for each other. I pay 100 Rs-200 Rs (USD 2-4) per hour. It depends on how big the chapter is, who is recording it, etc.*
>
> P16 (Female, Teacher)

> *We find readers through our friends. We pay a reader 500-1000 Rs (USD 8-16) per month for 1 hour every day. The reader reads the book and sometimes we record what the reader is reading and sometimes we just listen to it. We generally record important stuff using mobile phones. Readers record the material in two ways: some take the task home and give us the recording later, and others record audio content on mobile phones or laptops while reading material for us.*
>
> P10 (Male, Student, Master's)

Note that despite a professed preference for Braille, the user generation of Braille content is essentially non-existent. Production of audio content is relatively easy using a phone, laptop or audio recorder, but writing Braille by using a slate and stylus is difficult and time consuming.

5. DISCUSSION

This study is an account of offline, peer-to-peer propagation of user-generated multimedia content in low-income communities. Although there have been prior accounts of peer-to-peer media sharing in low-income communities, they have focused either on online sharing via Facebook [47, 48] or offline sharing of content pirated from professional sources or produced by full-time folk musicians [22, 43]. In the organic ecosystem uncovered in our paper, the content is shared offline and authored by ordinary people from marginalized communities in rural and peri-urban India.

Given the novel properties of this ecosystem, it is even more remarkable that it is orchestrated by visually impaired individuals. This demonstrates that the visually impaired community is not necessarily lagging behind in terms of technology adoption and use. These visually impaired users are leaders and early adopters in producing multimedia content to quench their thirst for educational material that is not available in other forms. The environment of constraint and disability has led to innovative uses of technology and created an ecosystem of content authoring and sharing.

The literature in the field of Information and Communication Technologies for Development (ICT4D) contains many examples of external interventions that failed to show sustained technology usage [3, 8, 11, 12, 15]. Prior research has documented that mobile phones are primarily used as a communication device and an entertainment device by low-income, low-literate people [23, 38]. The ecosystem discovered here is a rare example of educational usage of mobile phones by a low-income population, *without any outside intervention*. The content creation and sharing practices employed

by visually impaired people are organic and self-sustainable. The ecosystem reinforces the notion [28] that outside help may not always be needed for poor populations to apply new technologies in instrumental ways, i.e., ways that advance their long-term development and well-being.

6. RECOMMENDATIONS

Our study has uncovered a large gap in the demand and supply of educational content for visually impaired communities in India. Many of these challenges have persisted for several decades. Though a number of organizations produce Braille and audio content, most of the educational content is still inaccessible to visually impaired people because of the isolated efforts of these organizations. Content consumption devices, storage modalities, and sharing patterns have significantly evolved in the last two decades. The limited availability of Braille books and high quality audio books has resulted in an ecosystem where visually impaired people are creating and sharing their own low-quality user generated audio books. In the remainder of this section, we provide recommendations for technologists and policy makers to strengthen the informal ecosystem for content creation and exchange in visually impaired communities.

6.1 Strengthening Content Consumption Practices

Improve Discoverability of Educational Content

One of the most interesting findings of the paper is the near universal preference for Braille content by the participants. The majority of participants preferred reading Braille content despite having a thriving ecosystem of educational audio content creation and dissemination. Many participants considered audio as an inferior medium of accessing educational content. Participants associated pride, self-confidence, employability skills and high understanding of educational content with reading Braille.

The government of India in its 2014-15 union budget has announced establishing fifteen new Braille presses and reviving ten existing dysfunctional presses [18]. Though production of Braille content is critical, even more important is discoverability of the existing educational content in Braille format. The participants often expressed difficulty in finding new Braille content. Often they needed to reach out to a number of organizations to check for the availability of Braille content for college or competitive examinations, and frequently they were disappointed to find that the content was unavailable or inaccessible. The effort required to discover Braille content is so high that it discourages many visually impaired users from even trying to look. It also leads to redundant efforts between organizations that are producing Braille content, as it is difficult for them to know what is already available. Though there are 18 Braille presses in India owned by various NGOs and government entities [6], the efforts of these organizations are fragmented because of limited communication and coordination among themselves. The analysis of services offered by various government entities and NGOs also pointed out duplicated efforts in production of professionally authored audio content. Visually impaired people face the same challenges in discovering professionally authored audio content.

Thus our first recommendation, for technologists and policy makers, is to create a central repository that indexes the available Braille content and professionally authored audio content. It is also pivotal to distribute that index to content producers for reducing redundant efforts and enhancing coordination among themselves. A call center would be very valuable to enable visually impaired individuals to benefit from this information.

More Flexible Media Playback on Mobile Phones

Many participants experienced frustration while using mobile phones for listening to content because of inadequate support for rewinding or fast forwarding by a few seconds. This limitation exists in basic phones and low-end feature phones. To improve users' experience of media players on mobile phones, we recommend device manufacturers and application programmers to provide easy-to-use reverse and forward operations. In addition, implementing simple features like playing audio at different playback speeds (0.75x, 1x, 1.5x, 2x) will also enable visually impaired people to absorb and review information more efficiently. This feature will also provide benefits to sighted people.

Speech and Language Technologies for Local Languages

Though it remains a long-term research agenda, our findings confirmed the value of developing new speech and language technologies for languages such as Hindi. All study participants were native speakers of Hindi and most of them had poor English language skills. Screen reader software would have been more useful (and more sought out) by many participants if it was inexpensive and supported local languages. Though some researchers have started building speech synthesizers in Indian languages [34], significant work still remains to make it a reality.

Technologies for speech recognition of local languages would also enable better indexing and search of user-generated audio content, which most often was in Hindi. With effective speech recognition, visually impaired users can easily store and refer to audio notes on their mobile phones and other computing devices. These technologies will also need to be robust to variations in local language dialects.

Thus, we urge the research community to develop efficient and cost-effective speech recognition algorithms and text-to-speech systems for resource constrained languages.

6.2 Strengthening Content Sharing Practices

Easier Peer-to-Peer Mobile Media Sharing

Many participants reported using Bluetooth to share audio content with peers. A few of them reported memorizing the steps for using Bluetooth while others reported using a talking software or taking external help to share the content via Bluetooth. Some participants reported that exchanging information via Bluetooth is difficult because of issues in the Bluetooth user interface. The user interface for sharing content via Bluetooth remains very complex, including using paired identifiers to authenticate the transfer. Thus, we recommend technologists to create simpler Bluetooth sharing interface, perhaps leveraging audio instead of text to authenticate nearby devices.

Peer-to-peer sharing may also be simplified by leveraging smartphones. The smartphone penetration in India is growing rapidly with an annual growth rate of around 55% [27]. Because of the decreasing cost of smartphones, more people with low socioeconomic status will own a smartphone in the future. However, they will still remain very conscious of the fees of data connections, as mobile Internet remains expensive for low-income households, especially for large multimedia transfers. Thus, we recommend application programmers to develop new applications for simple peer-to-peer media transfer on smartphones. The application could synchronize folders on nearby devices in the same style as cloud services such as Dropbox, but using Bluetooth, NFC or peer-to-peer WiFi to avoid

the expense of transfering data to the cloud. Early work on projects such as Mango [19] are pursuing similar visions.

6.3 Strengthening Content Creation Practices

Better Audio Authoring on Mobile Phones

Seven participants reported using their mobile phones to record educational content, interesting comments by their teachers, and creative content such as songs and poems. However, this user-generated content is unstructured, non-indexable, and non-searchable. In addition, seven participants reported not using the sound recorder application on their mobile phone because of difficulty in navigation and use. Thus, we recommend application developers to create a user-friendly smartphone and feature phone application for authoring and managing audio content that uses the DAISY standard. This will enable creation of well-structured user generated content.

Enabling Long-Distance Dictation of Content

Many participants found it difficult to hire a local person to read and record their content of interest. They also reported paying around USD 1 for one hour of a reading session. Because of the ubiquitous availability of phones in India and low call costs (lower than USD 0.01 per minute using special plans from mobile operators), we recommend technologists and content producers to explore use of an IVR system to facilitate remote production of educational audio content. Visually impaired callers could request content that they would like to have in audio format, for example, specific sections of a common textbook. Workers or volunteers could call and record a section using the IVR system. They could be paid in the form of mobile airtime, sponsored by supporting organizations or perhaps via direct transfer from the visually impaired requester. Once the recording is available on the IVR platform, other visually impaired callers can play it back and create a local copy by recording the call. The set of recordings can also be organized and archived by the IVR host for broader dissemination via CDs, Internet, and other formats. This service could interoperate with the centralized index of Braille and audio content recommended earlier, creating a single clearinghouse for requesting, producing, and consuming educational content for the visually impaired.

7. CONCLUSIONS

This paper has elaborated the challenges faced by low-income visually impaired communities while accessing educational content, as well as the innovative solutions and coping mechanisms they developed in response to those challenges. We have conducted 16 qualitative semi-structured telephonic interviews of visually impaired students, recent dropouts, recent graduates, teachers, and content creation champions to better understand the educational infrastructure for low-income visually impaired people in India. Our systematic examination of participants' interviews reveals that access to educational content in Braille or as high quality audio is limited. This has significantly impacted the educational opportunities for an already disenfranchised community. Though some NGOs are producing Braille books and high quality audio books, they work in isolation. Moreover, the disparity in the demand and supply has led visually impaired content consumers to orchestrate production of their own audio content. Mobile phones are playing a critical role in educational content production, consumption and sharing by visually impaired people. Collaborative user-generated content production, consumption and sharing practices have emerged as a grassroots innovative solution to the limited availability of educational content. The paper also discusses various recommendations for policy makers to improve the educational landscape for visually impaired people, and for technologists to support the ecosystem of content creation and sharing.

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