# iSTEP 2015: Cross-Cultural Technology Development Toward Language Access for the Deaf and Hard of Hearing

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## ABSTRACT

This paper summarizes the work done over the course of nine weeks at the Mathru Center for the Deaf and Differently-Abled (Mathru Center) in Bangalore, India and aims to provide recommendations regarding technology solutions for deaf and hard of hearing students and their teachers in underserved communities. This work was carried out by a team of four undergraduate research students participating in an internship program called iSTEP – short for innovative Student Technology ExPerience (iSTEP) –organized by the TechBridgeWorld research group at Carnegie Mellon University. From the team's work in designing and developing educational tools with student and teacher participants, this paper explores the practice of creating shared ownership over technological ideas through direct relationship with the target population and viewing them as equals in the process. The team's partnership and work with the Mathru Center resulted in two newly created educational tools aimed at providing language access for Deaf primary school students and their teachers. The first, *SignBook*, provides greater sign language access through a sign language dictionary creation tool with abilities for custom video and picture capturing and categorization of entries and words into topics. The second, *Speak Up!*, motivates students to strive for greater verbal language access through a suite of voice-powered games aimed to familiarize pre- and partially-verbal users with the power of their voice.

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# INTRODUCTION

## TECHBRIDGEWORLD

TechBridgeWorld (TBW) is a research group based in the Robotics Institute at Carnegie Mellon University (CMU). The group forms and builds upon partnerships in underserved communities internationally to create culturally appropriate technology that adheres to each community's vision of progress. Founded in 2004, TBW leads the innovation and implementation of solutions that help address challenges in communities not ordinarily served by technology development efforts [[1]]. This work often involves the invention of new tools and customization of existing technology as well as efforts to inspire and train future researchers and technologists in this kind of work. TechBridgeWorld employs the knowledge and imagination of faculty, staff, and students in all of its projects. TechBridgeWorld aims to create technology solutions accessible and relevant to all to improve people's lives, enhance and share advances in technology across cultures, and promote sustainable development around the globe.

## ISTEP

TBW launched the Innovative Student Technology ExPerience (iSTEP) internship program in the summer of 2009 to provide CMU students with real-world experience in applying their knowledge and skills toward serving marginalized or underserved communities. Through a unique 10-week summer research internship, students conduct technology research projects alongside partner communities across the world.

iSTEP offers selected students the opportunity to engineer with compassion through first-hand experience. Over the years iSTEP has brought together intern teams of undergraduate and graduate students from CMU's Pittsburgh and Doha campuses with diverse experiences and disciplinary backgrounds. Together with TBW, each iSTEP team collaborates with local partners to better understand the needs of the community and design technological solutions that could help address some of the challenges that the community faces. As part of TBW's philosophy, all solutions are built with the community and developed through trust.

Past iSTEP locations included Tanzania in 2009, Bangladesh in 2010, Uruguay in 2011, Ghana in 2012, and India in 2013 with projects in assistive technology, literacy tools, information exchange, and environmental sustainability [[2], [3], [4], [5], [6]].

The multidisciplinary iSTEP 2015 team was comprised of four undergraduate students from various schools at CMU including the Carnegie Institute of Technology, College of Fine Arts, Dietrich College of Humanities and Social Sciences, School of Computer Science, and the BXA Intercollege Program. iSTEP 2015 interns have built upon the iSTEP 2013 team's work by developing new assistive technology projects in collaboration with TBW's partner, the Mathru Educational Trust for the Blind.

## The Mathru Educational Trust for the Blind

While now working with numerous global partners, TBW's longest standing partnership has been with the Mathru Educational Trust for the Blind (Mathru Trust). The Mathru Trust houses both the Mathru School for the Blind (Mathru School) and The Mathru Center for the Differently Abled (Mathru Center). Ms. Gubbi R. Muktha founded both schools after her own debilitating injury. TBW has been partnering with the Mathru Trust since 2006 to build assistive technology based on observed and communicated needs with continual community input and feedback. Additionally, TBW has been partnering with the new Mathru Center since its inception in 2012. In 2013, an iSTEP team completed a Needs Assessment report and since then, an ongoing partnership with the Mathru Center has continued.


**Figure 1. The Mathru Center for the Deaf and Differently Abled**

The Mathru Center was inspired after illness caused a blind student at the Mathru School to suffer significant hearing loss, thus being unable to continue on at the school without more specialized accommodations and support. Today, the Mathru Center is a residential school offering free education for students with hearing impairments or multi-sensory disabilities. The goal of the Mathru Center is to recognize the capability and power of all individuals, regardless of the limitations imposed by society and environment regarding physical ability. The Mathru Center currently has 47 students of which 31 are deaf and hard of hearing students and 16 have multi-sensory impairments. While this year the Center serves students from nursery to 4$^{th}$ standard, additional standards will be added annually as students grow into the next grade. The curriculum for the Deaf students at the Mathru Center follows the state syllabus as well as teaching the additional curricular needs of speech and sign language.

## Information Communication Technology for Development in India

Though Information and Communication Technologies for Development (ICTD) is a young discipline, India has been an epicenter of research and field studies in this area [[7]]. The surge of Information and Communication Technologies (ICTs) in India has been growing for several decades, starting from India being the first country with a computer in the global South

in 1956 [[8]]. This has created a space for incredible empowerment as well as imposed solutions.

Technological development that caters to users in the Global North often makes assumptions that are not true of developing countries. To name a few: reliable power, Internet access, previous experience with technology, and literacy. In India, a country with only 12 Internet users per 100 [[9]] persons and unequal literacy rates across states and demographics, these common assumptions by developers deny large Indian populations from technological support [[10], [11], [12]].

For further marginalized groups, such as the disabled, access to and experience with technology is likely even more limited [[13]]. Thus, additional provisions were taken to ensure a solid understanding of the unique needs of our partner, the Mathru Center. Likewise, it was critical to employ participatory and empowering stances in both the creation and evaluation of our work.

## Culture and Community

Currently, 360 million people worldwide have disabling hearing loss, which the World Health Organization defines as "hearing loss greater than 40 dB in the better hearing ear in adults (15 years or older) and greater than 30 dB in the better hearing ear in children" [[14]]. Individuals with disabling hearing loss have trouble hearing everyday conversation or perceiving sound in even quiet environments. As it stands, only 10% of the global need for hearing aids is met, 90% of the world's deaf population has never been to school, and only 5% can read or write. The prevalence of hearing loss is unequally distributed across the world with 80 percent of the world's deaf population living in developing countries [[15]]. Additionally, South Asia has the highest rates of deaf and hard of hearing individuals while the current production of hearing aids meets less than 3% of developing countries' need [[1]]. In turn, South Asian Deaf communities face increased challenges and hardships.

Under India's Persons with Disabilities Act of 1995, the integration of disabled communities into mainstream society was established as a government priority [[16]]. However, official documentation of sign language has been disregarded and unsupported, thus keeping India's Deaf community from being widely understood and recognized.

Our work with the deaf and hard of hearing community at Mathru Center addressed two complexities. First, while the Mathru Center hopes to increase access to sign language, Indian society as a whole neglects sign language and thus prioritizes verbal language as a necessary part of deaf peoples' societal inclusion. Therefore, work in this area must acknowledge the present expectation of verbal communication as a path to self-advocacy for the Deaf. Although India's Deaf culture is growing, they are still decades away from having the same support and recognition seen by American Deaf culture - so much so that it would be

disadvantaging Mathru Center students to not enable verbal language access alongside sign language education [[17]].

A major difficulty that is somewhat unique to India's growing Deaf community is the vast multitude of existing verbal languages. This situation can lead the Deaf to feel societal exclusion across all of India's diverse language-scape in both the hearing and Deaf communities. Thus, deaf individuals in India experience the unique challenge of having to bridge a multitude of signed languages on top of a multitude of verbal languages. In India, deafness often assumes dumbness – the cognitive inability to communicate. This, along with India's cultural denunciation of sign languages, bars India's Deaf communities from support in both signed and spoken languages. Despite an increasingly global world, Deaf communities remain disconnected due to a lack of understanding, lack of interpreters, and lack of societal respect for sign languages [[18]].

The main "justification" for the linkage between deaf and dumb is the delayed speech and communicative development of deaf children. However this delay is in spoken language, an unnecessary metric if provided access to sign language [[19]]. Speech therapy remains prohibitively expensive and time intensive. Because the Mathru Center also lacks the resources to fully invest in individualized daily speech therapy, progress is slow and unfruitful in the short span of the school year. Access to spoken language remains difficult to incorporate and utilize in education for deaf Indians, yet they would be fully able to participate in society if given support and encouragement [[16]].

Efforts like the Azim Premji Foundation (APF) in Bangalore, India and the Digital Information Research Foundation (DIRF) in Chennai, India have set up thousands of centers across India to give access to shared computers with priority for the deaf and disabled. However, APF coursework uses largely audio-based local language instruction and DIRF aims to give opportunity for technical literacy for the deaf.

Very few of our related sources focus on the considerations of early Deaf education or if they do, assume a higher than present familial support network [[20]]. We aimed to create assistive tools that would standalone in function but not replace the power of the teacher. Existing projects considered accessibility in one sense, but none addressed the key constraints at the Mathru Center: low technical literacy and students with little means for communication.

Our work identified and addressed two main hurdles that exist for marginalized deaf Indians and their access to language and communication: firstly, formal language expression and formation through sign language, and secondly, awareness of voice and the effect it may have. The former requires more training and support by teachers, who need to teach and encourage sign language acquisition to students [[21]]. The latter is a necessary prerequisite for verbal language formation but is too often coupled exclusively with speech therapy. Our work follows the idea that awareness of voice and the power it has can be additionally supportive in formal language formation and learned without the need of a trained speech therapist.

The goal of the TechBridgeWorld-Mathru partnership and the work of this team has been to create assistive technologies that serve and empower the Mathru Center community. Based on a prior needs assessment at the Mathru Center (further detailed later in this report) the chosen focus of our work is to explore language access at the Mathru Center via both signed and verbal means. While creating agency through our custom sign language repository, we also acknowledge the need of the Mathru community to use speech therapy for instruction in immediate skills to assist students' access to the broader Indian society. These projects begin to tackle the groundwork of technology to assist the communication of the deaf and hard of hearing in India: both in an increased recognition and access to local sign languages and in the training of verbal language through speech and one's voice.

## iSTEP 2013 Findings

The 2013 iSTEP team performed a needs assessment at the Mathru Center to identify key areas of difficulty or complexity in teaching to the differently abled students at the Center. This included a two-fold consideration of teaching methodology and student needs. Through observations, shadowing, affinity matching, and interviews, the 2013 team identified key problem areas inhibiting teacher efficacy [[17]].

The findings through this needs assessment recognized that the most prevalent teaching tool, flashcards, had both temporal and physical restraints. Temporally, flashcards took a long time to sort by subject area and difficulty, leaving teachers with less time to teach. Physically, flashcards are a limited medium requiring teachers to present cards to an entire group with varying ways of learning, making it challenging for material to be customized to each student's needs. Teachers provide a lot of individual attention because students are at varying skill levels, but that proved to be challenging with existing tools and resources. Interestingly, the report noted that teachers felt that students learned faster from each other.


Figure 2. Flashcards used at the school

Another significant limitation identified was teacher training. Because the Mathru Center is in its infancy and India as a whole lacks teachers trained in education for deafness and multiple sensory impairments, the Mathru Center at the time had only one trained teacher during the summer of 2013. Thus, they rely in part on teachers without experience or training in special education to lead classrooms, whose lack of background experience and high turnover leads to many challenges relating to training and classroom efficacy.

The 2013 iSTEP team suggested a few problem spaces in which a new technology solution could be useful. The main suggestions for teachers included a teacher training reference for teachers to develop their skills and teaching style from published online resources and compiled notes from trained Mathru Center staff. This included a sign language training tool for untrained teachers, but this was noted as being difficult as the sign language used at the Mathru Center is a dialect of Indian Sign Language that has very little existing documentation.

Another recommendation for future work was a flashcard generator and lesson planning technology. These directly respond to teachers' observed difficulties in the time spent preparing lesson plans. Such a tool's database of words would need to consider a wide range of words and high quality images that are also culturally relevant and available. It would also need to recognize that the Mathru Center currently does not have Internet access, and thus would need to work locally on the computers at the Mathru Center.

The report also noted that teaching speech and word pronunciation was time-intensive and difficult for teachers, thus leading to a suggestion of speech practice software. This software could help assess and give feedback to students about the correctness of sounds they are making.

Other noted technology solution suggestions included Computer Training, Sign/Alphabet Translating, and a Multi-Sensory Classroom Assistant to support the wide range of students attending the Mathru Center.

## MOTIVATIONS

The iSTEP 2015 research team aimed to address the foremost challenges affecting teachers and students at the Mathru Center with newly developed and customized technology solutions. According to the iSTEP 2013 team's needs assessment at the Mathru Center, one of the biggest challenges at the Mathru Center was teacher preparation and training. In addition to validating this need through conversations with head staff and teachers, the 2015 team also assessed additional needs of the Mathru Center where technology may play a role. As a result, we have iterated designs and deployed early versions of educational technologies that address sign language access and speech therapy at the Mathru Center.

This report informs the work of future teams and the TBW research group on assistive educational technologies initiated during the 9-week field research internship at the Mathru Center. Secondarily, this report can serve to educate onlookers of the ongoing partnership between TBW and the Mathru Trust, as this report demonstrates the particular and unique considerations taken when developing for the deaf and hard of hearing community. Lastly, this report hopes to express the importance of ownership and empowerment when working with developing communities. In particular, this project contributes to the growing body of work

aimed to holistically develop technology that empowers and frees rather than imposes and assumes.

The remainder of this report will provide an in-depth look at the iSTEP 2015 projects. We will discuss methodology, study structure, data collection tactics, unforeseen considerations, and related works in developing our solutions. We will describe the solutions developed and then conclude our report with a discussion about our reflections and our considerations for future work.

## Language Access Tools

The 2015 team arrived at the Mathru Center for the start of the 2015-16 school year. It was important for us to validate the needs uncovered by the 2013 team, particularly given that two years had passed and the Mathru Center is a young institution. In our first three weeks into the summer, two out of the three existing teachers for the deaf and hard of hearing quit and all the new hires were not trained in educating deaf and hard of hearing students. One reason for the high turnover of teachers at the Mathru Center could be tied to Indian culture: many teachers are young, unmarried women, who often are pressured to leave teaching when expectations of marriage arise. On top of these challenges, we realized that the findings of iSTEP 2013 assumed a higher-than-present level of technological feasibility in the classrooms of the Mathru Center. Hence, our projects needed to consider another ground up needs assessment to identify feasible technology solutions, if relevant.

We discussed difficulties experienced at the Mathru Center with both exiting and new teachers, as well as administrators. Teachers were concerned with the shyness of expression and communication of their students. Students would not be able to express, through sign, verbally, or otherwise, when they were upset or confused. This is probably linked to the varying dynamic of the teaching staff and inconsistencies with in-class behavioral rules. Further, as pointed out in the 2013 report, students have difficulties communicating with each other due to differences in the sign language used at the school. Administrators, on the other hand, were concerned with the lack of teacher training tools and student difficulty with verbal communication. The lack of teacher training tools resulted in a large learning curve for new teachers, and a less effective use of class time. Students' difficulties in speech were a concern for the administrators because, outside of the Mathru Center, students would need to rely on verbal means as the main method of communication.

We used these experiences to direct our projects created in the field. Our process consisted of spending two days a week at the Mathru Center for observations, interviews and user testing. Our field notes comprise of hand written notes, photos, and videos.

### Study Setting

The Mathru Center is a residential school complex that has developed the following services:

- Free Hostel for Differently Abled Children
- Center for Deafblind and Multi-Sensory Impaired (MSI) Children
- Vocational Training Center for Disabled and Women
- Free School for MSI Children
- Free School for Deaf and Hard of Hearing Children (4 classrooms)

Figure 3. First grade speech class

Our observations and interviews were held after daily classes ended. Our regular point of contact was the most senior teacher at the Mathru Center, who gave direct feedback on our ideas and shaped our tools into value sensitive technology applicable to the classroom. We consulted students and new teachers multiple times during our development phase, keeping the Mathru Center community included in all parts of creating our language access tools.

After developing our language access tools, user testing in- and outside of the classroom was conducted using laptops donated by TBW to the Mathru Center. Laptops were purchased because teachers preferred using laptops over using the existing desktop computers at the school and a set of two tablets donated to the school.

## Study Participants

We obtained full participation from all teachers in the Center according to the Carnegie Mellon University Internal Review Board (IRB) protocol for non-invasive work with human subjects – including the teachers who resigned during our time at the Center. We obtained consent from all students in the deaf and hard of hearing classes, first through fourth standard, for participation in the study. At least two team members were involved in every informed consent process. Our interviews with teachers and students were conducted in English, sometimes with either a staff member or other teacher present to translate into either Kannada or Hindi.

## Findings and Development

When considering solutions to the needs found in 2013, we foremost found a lack of sign language documentation used by the Mathru Center community. Lack of sign documentation is what predominately keeps new teachers from gaining an understanding of student aptitude-a significant need considering the wide range of ability at the Mathru Center. Because teachers needed to learn signs from students or other teachers, common classroom power balances were challenged. This provides an interesting existing social structure for a potential sign language reference made by Mathru teachers and students for other Mathru teachers and students.

We also saw that teachers for the deaf and hard of hearing continued to include a speech class during the day despite not being able to afford professional speech therapy. Basic sounds and everyday vocabulary are practiced via a speak-and-repeat method, paired with bringing students' hands up to a teacher's throat to feel the vibrations and emphasizing lip-reading. The main limitations of speech class were that students were shy to speak, would not know the difference between mouthing words and speaking, and the teacher could not provide extensive individual attention. These observations are not applicable to the MSI classroom, in which the curriculum includes individualized plans created with quarterly benchmarks towards an annual goal. Some MSI students then have more speech training if relevant to their personal goal, though the 2015 team did not observe those sessions.

Although we had initially hoped to utilize the existing computer lab at the Center, the computer lab was not a reliable resource. The computers were underutilized and not maintained, many of which were virus-ridden or lacking functional hard drives. Due to this and an interest in bringing technology to the classroom, the Mathru Trust and TBW invested in two Lenovo laptops to house our iSTEP 2015 projects. Teachers chose these laptops over tablets because they will "give students a better idea of a computer." We found that students and teachers were happy to adapt new ways of learning and teaching but did not have the confidence to demand such resources themselves. To begin working with the complex and new environment of the Mathru Center, our development was catalyzed by the information provided by the iSTEP 2013 team and prior knowledge held by iSTEP 2015 team members.

### *SIGNBOOK: A SIGN LANGUAGE DICTIONARY*

Deaf communities around the world utilize a diversity of sign languages, but only until the recent past have sign languages begun to receive recognition as fully complex and structured languages capable of rich meaning and abstract expression [[15]]. This is in part due to misconceptions of the deaf as the "deaf and dumb" or "deafmute" and of sign language as a language of simplistic gestures [[22]]. Still today, according to the World Federation for the Deaf, only 44 of about 120 countries recognize sign language as valid languages for use in schools and other official matters (such as in government) [[23], [15]].

The Ethnologue, which is the most comprehensive record of the world languages that exist, compiled by hundreds of linguists and researchers since 1951 with over 7,000 living languages listed and categorized, notes a mere 137 documented 'Deaf sign languages' in the world with approximately 10.5 million speakers [[24]]. Compared to the estimated 360 million with disabling hearing loss [[1]], even knowing that many of those do not use sign language, there seems to be evidence of a gap of discovered and researched sign languages and Deaf communities.

As one linguistic field researcher notes about sign (visual) languages:

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*…manual visual languages were not recognized as languages at all. Rather, as Bloomfield put it, "… elaborate systems of gesture, deaf-and-dumb language, … and so on, turn out, upon inspection, to be merely derivatives of language" (1933, p. 144). Severe under-documentation of an entire class of natural human languages is the unfortunate legacy of this historical failure to recognize and to attend to sign languages as languages. To date, "There has never been a thorough survey of the world's sign languages" (Meier, 2000, p. 1965), and most of the world's manual visual languages have yet to be described. [[25]]*

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He goes on to write that the under-documentation and recognition of sign languages is especially true of "village" or "indigenous" sign languages, which is the type used at the Mathru Center. This unfortunate history of sign languages being disregarded leaves a hole in the world's recognition of not only the language of the Deaf, but the knowledge of Deaf cultures and the needs of this largely ignored and undervalued segment of the global population.

Of efforts made to assist the deaf in developing communities, many do not take a people-centered approach in recognizing the voice and thoughts of the deaf they aim to help. For example, much philanthropic work has been done to assist the Deaf community in Kenya, including the development of a sign language dictionary on CD and distributed within Kenya [[26]]. However, a local Deaf Kenyan speaks of this and other projects quite negatively, saying: "these organizations have never appreciated community entry approaches, view the Deaf as objects of benevolence and not partners in development and are 'copy/pasting' foreign solutions to complex local issues" [[27]].

With the development of *SignBook*, the iSTEP team's approach valued the local sign language as a valid language and encouraged its use for education and communication at the Mathru Center. Throughout the project, we closely listened to the needs and perspectives of the teachers of the deaf and hard of hearing and the students from the very beginning. Through that we came to a set of features that addressed the needs of teacher training, having

a sign language reference, and providing a customizable, efficient, and reusable teaching tool. Together, we created *SignBook*, a digital tool for creating a community-constructed sign language dictionary. We hope this work contributes not only to assist the needs of the Mathru Center, but also to further a community-centered vision of ICTD work, document our steps in cross-cultural creation of assistive technology for the deaf, and more broadly, promote awareness of the legitimacy of sign language and the needs and desires of the deaf around the world so that more and more of the deaf population can be empowered towards becoming increasingly valued members of society through adequate access to language and education.

**Related Works**

This project is the first that empowers Deaf communities to be able to document their own sign language through a digital application. Additionally remarkable is that no prior ICTD work addresses deaf sign language learning [[28]]. Though this is a relatively original project concept and customized to the needs of the Mathru Center, several components of the project do build off the concepts and ideas of existing works.

The idea of a video-based sign language dictionary has been around for over 15 years. Online are several sign language dictionaries with thousands of words and videos of signs in American Sign Language [[29], [30], [31], [32]]. The most feature-rich of these, Signing Savvy, features word entries with descriptions, images, memory aids, English examples, synonyms, ability to print signs out on paper, multiple videos if there are multiple meanings, and more. It also allows for the ability to create word lists of your own that can be used as flashcards or in quizzes and has a mobile app for smartphones and tablets [[32]].

The idea of a community constructed and customized dictionary has also been implemented online in different ways. One method has been through sign language wikis that have been established, usually with the help of a research group, that utilize the collaborative power of wikis with sign videos posted through YouTube or similar means that allow one to record a video from their own computer webcam. These sites have been replicated and used for a wide variety of sign languages including Finnish Sign Language and German Sign Language [[33], [34]].

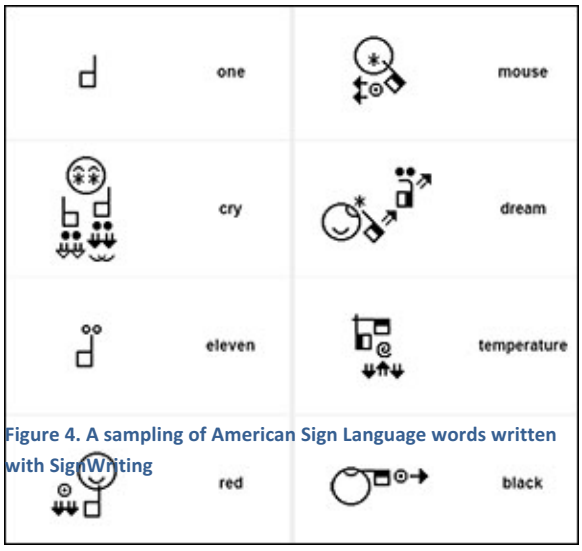

Figure 4. A sampling of American Sign Language words written with SignWriting

Another community constructed sign language dictionary site, SignPuddle, uses a written version of sign language called SignWriting (see figure 4), originated in 1974 in Denmark [[35]]. SignPuddle has a tool used to

create signs in SignWriting and then allow one to add it to the database and dictionary of signs [[36]].

Lastly, an unreleased technology device titled UNI which mainly serves to translate sign language to speech and text is also marketing to include with its release "the world's first easy to use sign adding software" for creating customizable sign language dictionaries as well as cloud management software to upload signs, share signs, and further combine sign dictionaries together [[37]].

Taking all of these existing solutions into account, there is much to draw from but no existing solution could address the Mathru Center's needs. Most importantly, the Mathru Center currently has no Internet access, rendering any online sign language dictionary out of reach. Further, the school does not have the capability to learn and use a written system of sign language to document their local sign language. Many existing interfaces are also time-intensive to document signs, such as the process of creating and uploading a YouTube video then creating a new wiki page for each sign, one at a time. Thus an ideal solution for the Mathru Center would allow for a quick way to record sign videos and store them as words in an organized database of signs that are also quickly accessible as a dictionary reference.

We also looked in depth at the visual presentation of materials in an educational setting [[38]] and consulted other digital flashcard applications to shape the visual presentation for SignBook including Quizlet, KitzKitz, and Cram [[39], [40], [41]]. Quizlet allows users to place both images and text on flash cards, and record audio to go along with it. KitzKitz's sole purpose was printing flashcards, however, we found the interface difficult. Cram offered different views (mixtures of front and back) of the flashcards.

## Methodologies

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*"Another indication of the status of sign language in a country is the existence of one or more sign language dictionaries. A dictionary is a fundamental tool to both promote the status of and enhance the use of sign language" [[16]].*

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During the first three to four weeks at the Mathru Center the team engaged in many conversations with teachers, spent much time observing in classrooms, and even had everyday casual interactions that helped the team slowly but surely understand more about the school and build connections with the teachers and students.

The team had been initially told that the school used American Sign Language (ASL). One of the team members, having a background in ASL, recognized a few signs in common with ASL, but quickly realized that the school used another sign language altogether. Asking the project manager more about the sign language that was used, the team was given an Indian

Sign Language (ISL) dictionary titled “Talking Hands” [[42]]. However, this set of signs also had some overlap but was found to definitely not correspond to the sign language used at the Mathru Center. Eventually, one book was found with beginner signs with Kannada captions (the local language of Bangalore) with around 480 signs contained in it. This book was the closest we found to the locally used sign language, but there were still some major differences between the book and observed sign language, usually observed when signs seemed to be adopted from ASL and ISL such as the days of the week being the same as ASL. The Kannada book of signs also contained only nouns, lacking even basic pronouns and verbs, which are vitally necessary for language and expression.

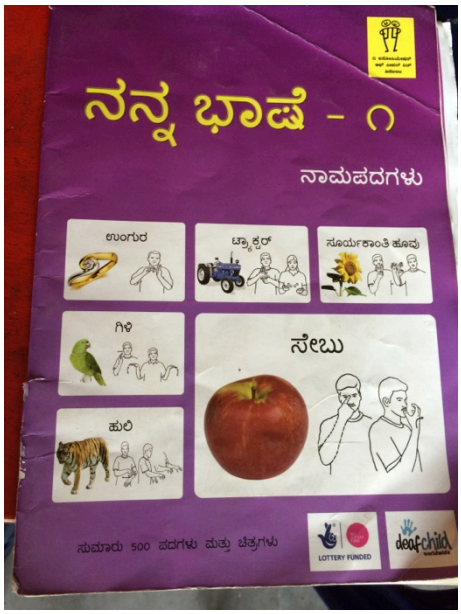


**Figure 5. “My Native Tongue – 1” The only official sign language reference book at the Mathru Center**

This series of observations and findings led to the main discovery that inspired the creation of *SignBook*: there is no existing comprehensive reference or dictionary for the sign language used at the Mathru Center. The suggestion of a school dictionary was identified in the 2013 report about the Mathru Center, but knowledge of just how scarce the resources were for the local sign language was surprising to the team and highlighted the need for some form of community reference to learn from and to be used in teacher training.

Through classroom observations we further noticed that teachers often used fragmented sign language sentences while the children used more complete sentences, as they relied on sign language as their main form of communication. Many teachers, especially new teachers, would use one or two signs in a sentence and talk loudly the full English or Kannada sentence they were saying. However, the children would often look confused if the sign and facial expression of the teacher did not fully capture the sentence meaning. This indicated that the students were heavily reliant upon sign while the teachers were more verbally focused due to a lack of fluency in sign language. These observations further underscored the need for a sign language dictionary reference for teachers to learn, train, and practice from.

An important note on our methodology in these observations is that we aimed to be as unimposing and nonintrusive as possible. In many early observations, the teacher would ask the ASL speaking team member, what the American signs were for different words, and subsequently introduce them along with her lesson plan as alternative signs. Realizing that this could add complication to teaching the primarily used local sign language, showing ASL signs was stopped during observations.

The described series of events follows a greater phenomenon common in cultures with village sign languages as described in *Research Methods in Sign Language Studies: A Practical Guide*:

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> *"One of the reasons why sign languages may remain undocumented for a long time is their coexistence with a larger or more prestigious sign language, which often leads to a negative perception of the local sign language and to a subsequent tendency to not overtly identify with its use and/or to shift to the prestigious sign language." [[43]]*

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This quote explains reasons why the school staff perhaps did not identify as having a local sign language at the beginning and were eager to learn from a more prestigious and widely used sign language like ASL.

Other insights gleaned from classroom observations were that many lessons are topic-driven. Every class observed had a set of words or facts for the students to learn by the end of the period. This topic-driven teaching style led to the topic-organized categorization system of *SignBook*.

Classes were also very visually based. When a teacher could not find a flashcard or poster for the subject to describe, teachers would sometimes spend up to several minutes drawing an intricate drawing on the chalkboard showing the subject matter while the students were left unengaged with any material. Even after school, as the 2013 report mentions, teachers spent hours preparing cut-outs of pictures, organizing flashcards, and hand-drawing other drawings for use in the lesson plan and in class. This motivated the inclusion of pictures in *SignBook*, and methods for uploading existing images or taking pictures to allow for any conceivable and simple way to add images to digital dictionary entries. Going over this idea with one teacher, she remarked that it can take much description and effort to connect a written word and visual sign together to represent a unified concept for a deaf child, but seeing the *SignBook* dictionary entry, the student will be able to instantly understand the concept.

Figure 2: An illustrative drawing by a teacher, used to explain classroom lessons, in a first grade classroom.

## Development

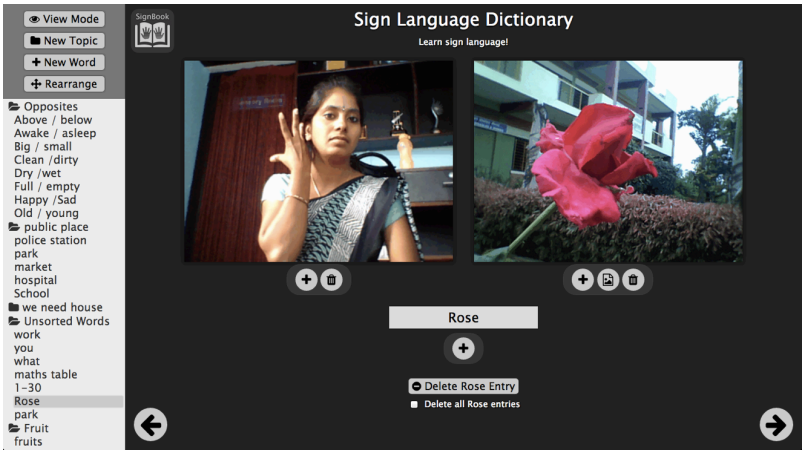


Figure 7. The SignBook interface

Early interviews with teachers revealed a preference toward laptop applications over tablet applications. Based on the team's programming knowledge and the requirements of the application, the programming environment was chosen to be in web languages (HTML, CSS, JavaScript, PHP) but be completely locally hosted, meaning the web application would not rely on the internet but use only files on the computer itself. This choice allowed for more rapid frontend development, cross-platform compatibility, and future potential of transferring the application online for broader use and availability. This also promotes the learning of common computer literacy skills desired by the school, to use a web-based application on a laptop. Many open source libraries were used including Google's Angular framework, RecordRTC for video and picture capture, and PHP Desktop for allowing the application to work like a native Windows application.

The features of the application were developed in correspondence to the needs of the Mathru Center and iteratively developed and modified based on user tests with teachers. Table 1 (below) features developed over the course of the nine weeks, their descriptions, and what needs they were based upon.

| Feature | Description | Need Addressed |
|---|---|---|
| **Video Capture** | Recording tool to quickly create a .webm video file from the webcam and connect it with a dictionary entry | Simple and fast way for teachers to document signs |
| **Picture Capture** | Similar capturing tool for a .gif picture from the webcam to connect with an entry | Fast way to "scan" existing flashcards and images or to show physical objects and places |
| **Picture Upload** | Upload any image file as a picture for an entry | Can use pictures from other sources to add images not easily found nearby or taken via webcam |
| **Topical / Folder Organization** | Organize words into topics and sub-topics in a folder hierarchy | Organize the dictionary similarly to the topical nature of classroom lessons |

| | | |
|---|---|---|
| **CRUD Operations** | Create, Read, Update, and Delete dictionary entries and topic folders | Necessary actions for management of any database system |
| **Multiple Videos** | Can have more than one sign video with a word | Allows for sign synonyms, sign variations, or even multiple sign languages associated with one entry (a local sign, ASL sign, etc.) |
| **Multiple Pictures and Meanings** | Can have more than one picture and meaning in an entry | Allows for a sign having more than one English meaning and multiple visual representations of a word |
| **View Mode Show / Hide Buttons** | Show / hide any combination of an entry's video, picture, and meaning in View Mode | Flash-card like usage of the sign dictionary (show the sign, hide the word, quiz the student) |
| **Cross-Platform Compatibility** | The application runs on Windows and (if Chrome is installed) Macs too | Current development was done on Macs, with school usage on Windows |
| **Fast Load Times** | Navigating between entries is done asynchronously (without new page loads) | Quicker to use and also less error prone in reading and writing from the database |
| **Keyboard Shortcuts for Navigation** | Arrow keys jump between words, other keys act as show/hide or next/previous shortcuts | Mouse movements between many frequently used buttons proved difficult and for teachers to use and slowed them down |
| **Help Text / Hover Text / Video Overlays** | Many instructions and functionality are provided via on-screen text, when you hover over a button, or over the video/picture capture screen | On-demand help and instructions assist new users in more quickly learning and remembering how to use the application |
| **Database Backups** | Backup files are saved of two key data structures once a day and recorded videos are never deleted from the computer | Data recovery is critical to be able to do when something goes wrong, and data loss could discourage use of the application |

Table 1. SignBook Table of Features

### Study Results and Reflections

Towards the end of our fieldwork, we trained the most senior teacher for the deaf and hard of hearing students and the main Mathru Center administrator on all aspects of *SignBook* with three extended training sessions, as well as two other teachers on the basics of the tool with one training session each. Through this training, teachers were able to create an initial vocabulary of 30 words across 7 topics, almost all entries including the three entry components of a word, video, and picture.

Teachers shared their responses to *SignBook* during training with positive and excited comments. One teacher remarked:

> *"This is very good because I can learn on my own and be fine teaching to the children. If I ask [the other teacher] she will teach me after 4:00 PM, but now I can ask and she will enter in this. I will see again, repeated, how to do the sign – it is the easy way! I can easily see this and then teach to the children."*

One of the main funders and supporters of the Mathru Trust, upon seeing a demonstration of *SignBook* commented that "Now anyone can document their sign language, and even give a copy to others to learn! This has so much potential. Potential to provide access to teachers, families, and communities to communicate with the deaf."

There was not sufficient time to observe classroom use of the tool, but an informal moment arose at the end of a teacher training when 15 children gathered around to look at what the teacher was doing. A team member led the children through View Mode for all of the existing words so far, showing and hiding the words and videos to quiz the students. They excitedly finger-spelled or signed the answers in response and exchanged a thumbs-up and handshake when getting the answer correct.

The future of *SignBook* is yet to be known, but initial reactions, users' quick learning and use of the tool, and excitement from teachers, students, and administrators show promising potential. Much work remains to be done in providing sign language access to Deaf communities around the world, especially the kinds of local village sign languages as discovered at the Mathru Center. *SignBook* is a unique and exciting start in using modern technology towards the effort to provide this kind of access. We hope the work and documentation of this project will continue on to inspire effort in ICTD work and assistive technology for the deaf and hard of hearing to give those who may not have ears that hear a greater ability to learn, communicate, and discover more of the knowledge and experiences to be had in the great wide world all around them, rich in vocabulary, visuals, and meaning.

A demo of *SignBook* is available online at http://erikpintar.com/signBookDemo.

### *Speak Up! Voice Powered Game Suite*

The majority of the world takes the ability to communicate verbally for granted every day. Throughout history, voice has been the societal norm for communication; yet such communication remains inaccessible to deaf individuals [[44]]. In India this is often coupled with the assumption of dumbness – the inability to communicate. While this assumption is understandable in developing communities where deafness is often the result of conditions also affecting mental or other physical ability, it is in no way an accurate generalization of a deaf person's capabilities.

The *Speak Up!* Voice Powered Game Suite (*Speak Up!)* was inspired by a conversation with the founder of the Mathru Trust, Ms. Gubbi Muktha. She noted both the importance of speech in interacting with broader society, as well as explained the financial infeasibility of hiring professional speech therapists. She had previously hired a speech therapist for speech classes once or twice a week, however there was "not enough progress" to justify the cost. When given such small amounts of designated time for speech therapy and otherwise remaining silent, students cannot meaningfully improve their speech. While the expertise of trained speech therapists is necessary for formal language acquisition, many of the students at Mathru are pre-verbal and struggle to understand the power of their voice. We were inspired to develop *Speak Up! as a* means of encouraging students to enjoy using their voice and to develop more control over their vocalizations.

**Related Works**

Because Indian society presently does not support a notion of Deaf community, there is an expectation of the deaf to assimilate into broader culture. "People with communication disabilities are often assumed to be considerably less able than they really are" [[45]]. The goal of our voice-powered games is to empower and encourage deaf and hard of hearing students to speak for themselves. Our suite of games targets pre-verbal language skills in a fun and engaging way by having students modulate pitch, volume, and vocalization.

Speech therapy is one of the most important routes for deaf individuals to be understood beyond a community that uses sign language. The importance of early childhood speech therapy is also crucial, given that sound formation and production becomes far more difficult with age [[21]]. Yet, prohibitively expensive speech therapist fees keep the Mathru Center from incorporating regular professional speech therapy into their classrooms. The Mathru Center identified more sources/tools for speech therapy as one of their largest needs at the school.

While open-source speech technologies are still unable to provide robust and individualized speech therapy, we found a few packages that do support speech therapy for use with a trained therapist. One such package, *Video Voice 3.0* [[46]], requires a speech therapist to configure the games and practice modes, and allows the speech therapist to track their students' progress. Considering the Mathru Center serves students with widely varying communication disabilities, we hope that through voice-powered games, the Mathru Center students will gain more comfort in communicating and expressing themselves verbally outside of the classroom. Our games use a range of basic aspects of sound — volume, pitch, continuous vocalization, and timed vocalization— to control game play. Our code is documented and organized in hopes of encouraging further development. We developed the games' input metrics and user interface through conversations, interviews, and tests, with the constant hope of aiding in the most pressing difficulties of speech.

We transitioned from speech therapy tools to games due to our lack of training in primary education as well as the inability for our open source software to recognize singular phonemes. Unlike humans, speech recognition software often needs contextual data to properly identify words, data that would be absent when identifying isolated phonemes [[47]]. Phoneme recognition techniques have achieved as small as a 25% error rate [[48]], but even that is too large for the Mathru Center, given that many students are pre-verbal. Further, many members of the Mathru Center community lack technological confidence, so we were wary about using error-prone technology as the base of our suite. Hence, we decided to focus on other aspects of sound that are similarly instrumental in achieving effective verbal communication.

**Methodologies**

We designed *Speak Up!* to work best with a teacher or instructor present. This keeps the use of *Speak Up!* in control of the teacher and does not impose technique or style limitations. Our goal was to allow students to visualize their voice in as many ways as possible. Providing different interpretations of voice translates into an understanding of the different effects that volume, tone, and vocalization have. We wanted to offer a variety of modes and gameplay: modes that solely provide visualizations of voice, modes with no end that can be used by a teacher in a classroom setting, and modes with a clear goal that can motivate students to use different aspects of voice.

The *Speak Up!* process was informed by observing teachers' speech classes. The 1st Standard teacher focused mostly on individual sounds. She went one-by-one, showed the student the lip and tongue movements, held students hand on her throat or in front of her mouth so they could feel the vibrations or air, and had them repeat the sounds multiple times. This was very taxing and time-consuming for the teacher, and by the end her mouth was dry and she was exhausted. The 4th Standard teacher, on the other hand, focused on words and taught communally. She would show the students objects and flash cards, and say the corresponding word loudly, accentuating the lip and tongue movements. She would then lay the objects together on the table, say a word, and have the students identify the object she was referring to. This teacher later elaborated on her technique. "In this school we use signs, but outside of the school people don't. That is why we must teach students to catch lip movements."

From our classroom observations, we gained an understanding of the breadth of students' current vocal capacities. It was important for us to design the various modes of *Speak Up!* to be relevant and useful to students across the pre-verbal and partially-verbal spectrum. It was also crucial to make *Speak Up!* usable by many different systems and computers, not only the newest and most expensive machines.

**Development**

The *Speak Up!* project began with a broad sampling of related works and understanding local limitations of technological solutions: lack of Internet access, unfamiliarity with technology, and already full class schedules. Our original idea revolved around more conventional speech therapy techniques. We wanted to make an application that tells students to say a specific sound, and provides feedback on the sound they said (either by telling them what they said or scoring how close they were to the desired sound). However, after a significant amount of research into open-source speech recognition APIs, we realized that technology to understand individual phonemes does not yet exist. A large limitation of speech recognition software is the common dependency on context needed for deciphering words from sentences. The problem for us is that these sophisticated statistical methods need more than isolated sounds – precisely what we want to detect. For these reasons it became clear that our sound games were going to need a teacher's guidance rather than having its own sound recognition scheme. Further, with more research and observations at the Mathru Center, we realized that there are many aspects of voice other than speech that our technology can help students at the Center grasp.

We started off with two simple games: a battle game, which emphasizes timed vocalization, and a rickshaw game, which emphasizes continuous vocalization. We tested these two games with a teacher and three students after school, and the reactions were very positive. The teacher thought it was useful in making speech "fun" for students, and the students seemed to enjoy working together on these games. The teacher then gave us feedback for future games: she thought students would enjoy "funny" games, such as a game related to picking fruit from a tree.

While working on the Fruit Tree game, we also began developing games that respond to different volume and pitch levels. We felt it was important to show teachers all the capabilities of our game suite before focusing on one or two aspects for games. As we showed these games to teachers and students throughout project development, we realized that the concept of volume was relatively easy to convey to them. Teachers felt that volume games would be useful in strengthening student's voices, as well as explaining to them which volumes to use in which situations. However, the concept of pitch was very difficult to explain, and often got miscommunicated or misunderstood as volume. Based on this reaction, we shifted focus away from pitch games, and more towards volume and vocalization games.

Based on our observations of the 1st Standard class, we developed multiple Free Play games, which respond to any student sound and go on forever, to allow students to practice the sounds they are taught in a way that is not taxing to the teacher. Based on our observations of 4th Standard, we made a picture game; in which as the students speaks a picture gradually appears. This game allows teachers to add and categorize their own words

and pictures, and will allow students to practice saying words and associating them with objects in a more engaging way.

In the end, we developed 10 modes across three categories. The "Beginner Skills" modes: *Volume Meter* and *Pitch Meter*, focused on giving simple visualizations of aspects of voice. The "Free Play" modes: *Fruit Tree*, *Rickshaw*, *Collect The Fruit*, and *Picture That!* are endless, and are intended to be used in the classroom to help students practice words, sounds, and other aspects of speech. The "Games" modes: *Spaceships*, *Drive To Mathru*, *Flappy Bird*, and *Fish Game* all have clear goals and distinct ends. These games were intended to encourage students use different aspect of voice, and allow them to healthily compete with each other.

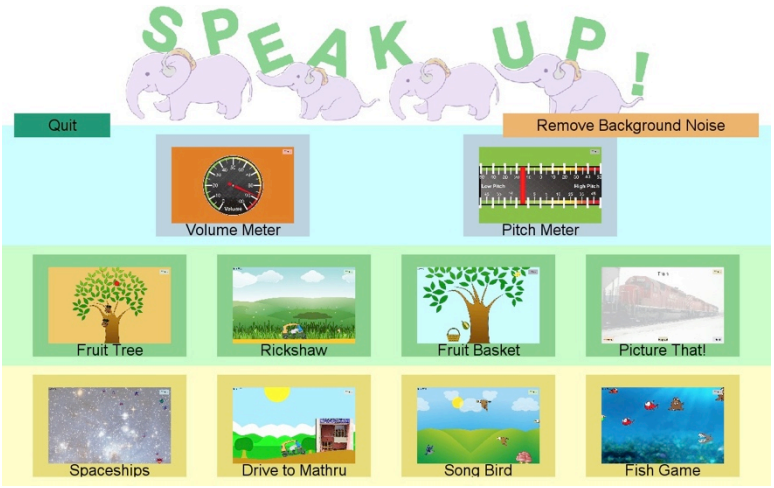


Figure 8. The *Speak Up!* main menu

**Study Results and Reflections**

In the last three weeks in the field we focused on training the teachers on how to use *Speak Up!* and were able to observe teachers use the program in class. One teacher had all the students sitting together around the computer using it communally. On certain games, she would have them watch her and mimic her lip movements for certain words. This was especially true with the *Fruit Tree* and *Picture That!* game, in which specific objects appear. With other games, she gave students instructions on how to use the games, and let them make any sounds with their voice to operate them.

Figure 9. A Mathru Center student using the *Speak Up!* voice powered game suite

Teachers began designating the library as the speech class space. The library provides a more open space where teachers have students gather around the laptop without obstacles like desks and chairs in the classrooms. One teacher also brought teaching aides to the library (animal models and flash cards), spread them out, and referred to them as students used the

games. The library is also a quieter room, isolated from other classrooms, which provides less noise interference in the games.

While it is too early to assess the impact of *Speak Up!,* the program seems promising based on formative assessments. There have been clear benefits of the sound games to individual students that we have observed. One student always made the lip movement for a word but never made sound; she did not understand how she could make sound. However, after just a few minutes with *Speak Up!* she began making loud sounds, and continued to make them throughout the games. Teachers were surprised at how excited and engaged students became when *Speak Up!* games were used. Though teachers are still trying out different ways to use the games in their class, so far P*icture That!* is the most commonly used, followed by games like *Rickshaw* and *Volume Meter*, which allow students to practice any sound the teacher wants them to make.

There are some areas of concern we have seen so far. Many of the games were intended for individual student use, but some teachers prefer using the program communally.

**Figure 10. A teacher using *Speak Up!* communally with her entire class**

The downside of communal use is that students tend to be making sounds in the background, so even when the teacher tries to focus on one student, other students' voices are the ones causing the change on the screen. This can be confusing and counter-instructive for students, as they may not be speaking and yet the game is recognizing voice. One potential solution would be to use the games with an external microphone, since seeing one student holding a microphone would encourage others not to talk. Unfortunately, we were not able to train the teachers on external microphone use, but it is a potential design decision worth exploring in the future.

When we observed one teacher using *Speak Up!* in class, she was so excited she used it for twice as long as a typical class period. She largely let students use it as they pleased, rather than incorporating it into her lesson. This raises the concern of whether teachers will continue to use *Speak Up!* even after we are gone, because it may not directly relate to school curriculum. Unfortunately, we were not in the field long enough to observe the novelty of *Speak Up!* fade. Thus, all teacher training, user testing, and observations we did were confounded by not being able to observe long-term use. However, during our last week in the field, we did witness the newest Mathru Center teacher using the *Picture That!* game with her third standard class. While we had not trained her specifically, she had learned how to use the software from the fourth standard teacher we had trained the week prior. She enjoyed using

the software and knew how to reopen, close, and shutdown the laptops; all aspects of training we covered with the other teachers. This demonstrates the potential for the Mathru Center community to self-train and spread knowledge to future staff and teachers.

## DISCUSSION

When technology is created with compassion and in respectful partnership with users, it can have the transformative power of affecting positive change in the lives of the disempowered. Together with the Mathru Center for the Deaf and Differently-abled (Mathru Center) and TechBridgeWorld, our team team explored how technology could empower the teachers and students of the Center's School for the Deaf.

Because of TechBridgeWorld's ongoing relationship with the Mathru Educational Trust for the Blind (Mathru Trust) since 2006, our team experienced the benefits that come with a strong partnership, such as trust and respect. We still had to build trust and did so by getting to know Mathru Center teachers, students, and staff. We also conducted a needs assessment to learn about the Mathru Center. While a previous iSTEP team conducted a similar needs assessment in 2013, it was useful for our team to understand the current situation at the Mathru Center. As a result of the 2013 and 2015 needs assessment findings, we developed two new educational tools. The first, SignBook, provided greater sign language access through a sign language dictionary creation tool with abilities for custom video and picture capturing and categorization of entries and words into topics. The second, Speak Up!, motivated students to strive for greater verbal language access through a suite of voice-powered games aimed to familiarize pre- and partially-verbal users with the power of their voice.

Figure 11. Mathru Center teachers creating a sign in SignBook

The tools were developed in close partnership with the Mathru Center. We tested prototypes of the SignBook and Speak Up! tools with Mathru Center students and teachers and with their feedback, we further improved the tools. When the tools were in a stable state, in the final weeks of the internship, we invested in the sustainability of the solutions by conducting extensive training with teachers and developing in-depth user guides. Furthermore, TechBridgeWorld released the tools open source so that others may benefit from these solutions as well as continue to enhance them in different community settings.

With these tools, which were created with compassion, we aimed to provide language access for Deaf primary school students and their teachers. Our work with the Mathru Center supported the process of enabling India's Deaf community in their campaign for self-advocacy through access to language. To disseminate this cause and raise awareness of developing technology with compassion, the iSTEP 2015 team gave a talk to over 100 engineering students at PES University in Bangalore. As a result of this presentation, a PES engineering professor has reached out to TechBridgeWorld about collaborating on technology projects with the Mathru Educational Trust for the Blind.

The future of this work is bright. Whether it is further development of SignBook or Speak Up! or an adaptation of developing technology with compassion, what the iSTEP 2015 internship was able to deliver after nine weeks in the field is an important record of community-specific ICTD work and two functioning projects by which to showcase it.

## Additional Considerations for Future Work

By the end of nine short weeks at the Mathru Center, the iSTEP team was able to create a SignBook, a local database of animations depicting a sign and is used to support new teachers and staff in learning the local sign language, and Speak Up!, a suite of voice-powered games that encourages students to vocalize and to exercise the volume and pitch of their voice. Much more can be continued in this work to create assistive technology for the deaf and hard of hearing.

**Figure 12. Technology is often treated as a novelty, since students do not encounter technology in everyday settings**

With *SignBook*, the team had just enough time to incorporate the key features as derived from our observations and interviews with teachers and students. The largest additional request that we did not have time to implement was for review and study games to go along with the dictionary database. An example of a review game could allow a teacher to choose any of the three display types (video, picture, word) for a question and then another display type for multiple choice answer options. This could be played with all words or just play through one topic's words. Functionality is also lacking with *SignBook* to merge words and topics from two dictionaries together, which limits the use of *SignBook* across computers and would be an

excellent enhancement. Further ideas for future work are summarized in *SignBook*'s developer documentation in its public online repository[1].

As we worked on the *Speak Up!* games and went through user testing, we realized the diverse use cases it needed to encompass. The students had widely different vocal capabilities in areas such as volume, pitch, and phoneme generation – the ability to make specific sounds. Additionally, because our games were used in extremely variant environments from the noisy classroom to the silent library, it was impossible to make games that accounted for all these deviations. We believe techniques from machine learning could greatly enhance the future of *Speak Up!*. Machine learning would allow the calibration menu to account for not only background noise levels but also background noise patterns, such as a chirping bird, a lawnmower, or relative silence. Machine learning in games that scale volume and pitch would allow *Speak Up!* to shift away from the absolute scale it currently uses, to one that customizes for each student. Perhaps extremely sophisticated machine learning techniques would allow games to recognize when students are getting closer to saying a word, a feature a teacher requested in *Picture That!* game. Unfortunately, we did not have the time or expertise to pursue these options in the field. Therefore, we tried to make the games as differently useful as possible. There is still a lot of room for improvement. There is no doubt that machine learning techniques will be extremely useful in helping *Speak Up!* reach the further levels of usability, usefulness, and adaptability.

One of the most important challenges we encountered when working with the Mathru Center was technological literacy. Future work needs to be careful about the use of technology that is current, but also locally available. Access to technology is limited – whether too expensive, hard to find, or otherwise unavailable. The Mathru Center did not have Internet and lacked a reliable computer lab. A major drawback to the Center's computer lab is that its donated computers are old or broken. After reinstalling Windows 7 and providing a basic computer training session for teachers, the incorporation of technology is now more feasible. Furthermore, we brought the Mathru School's computer lab manager to the Mathru Center to work on and assess the condition of the computer lab with us. We are confident that he can further support the technology needs of the Mathru Center on an as-needed basis, though additional work needs to consider the fact that no staff member is fully dedicated to technical support at the Mathru Center.

While we hope that the technology we introduced this summer continues to develop computer literacy, the Mathru Center also struggled with having a robust organizational structure. We have done our best to plant roots for sustainability with our technology projects,

[1] http://www.techbridgeworld.org/istep/downloads.html

we realize that true sustainability depends heavily on the organization and teachers continuing to train others and receive training on these tools.

We truly encourage future development and hope that future teams improve upon what we were able to do in such a brief amount of time. We want future developers to remember that ICTD work is not about product but also about process. There is no doubt about the aptitude and great skill of developers who chose to uptake ICTs. Without technical solutions truly understanding and being informed directly by the community they target, they will oftentimes miss the mark of efficacy and relevance. But by working hard to first develop and cultivate deeper levels of compassion, communication, and relationship, then ICTD work becomes more meaningful and more effective. This is the hope of ICTD, the hope of our work, and the call we give to future developers, designers, and researchers in this most rewarding, meaningful, and impactful work.

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# APPENDIX

## OUR FINDINGS AT THE MATHRU CENTER CLASSROOM FOR STUDENTS WITH MULTI-SENSORY IMPAIRMENTS (MSI)

The brevity of our field experience kept the MSI classroom outside the scope of our projects. While we were not able to develop new technologies specifically for the MSI classroom, we did observe the class multiple times and had discussions with the MSI teachers about the most inhibitive problems in their work. The most difficult circumstance in the MSI curriculum is that it is unique for each student; we could not rely on the same academic structure that afforded the adoption of our tools in a given fixed context. So with the curricula of MSI students being built individually, the MSI teacher suggested using a "creative practice" through which a tool could work for multiple students. The suggestions for future work as told by the MSI teacher include high contrast imaging, tactile storybooks, and sensory tools. These project ideas are "things that would help many students" because they explore different sensory exercises as well as provide creativity and enjoyment.

A difficult part of the Mathru Center system is the varying levels of family and parent engagement. Most students at the Mathru Center are residential, however MSI in particular also has home-based and day students. While technology is not viable in the homes of most Mathru Center day students, tools that encourage engagement with local surroundings and communities could create potential ways for parents and families to engage with the Mathru Center education.