iSTEP 2013: Exploring the Feasibility and Suitability of Assistive Technology at the Mathru Center for Differently-Abled

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Abstract

The use of assistive technology has been found to enhance the educational experience of disabled students and improve their learning outcomes. In low-income countries, however, finding inexpensive and sustainable assistive technology is a challenge. This report outlines key findings pertaining to a comprehensive needs assessment undertaken at the Mathru Center for Differently-Abled as part of the iSTEP 2013 internship program, organized by the TechBridgeWorld research group at Carnegie Mellon University. The objective of this study was to understand whether and how assistive technology could be used to enhance the learning and teaching experiences of students and teachers at the Mathru Center for Differently Abled. Researchers interviewed teachers and staff, conducted observations of critical activities at the center both inside and outside classroom, elicited opinions of a local special education expert, and administered participatory design experiments with teachers and affinity matching with students. Results indicate that there are indeed possible technology interventions that could benefit the students and teachers at the Mathru Center through reducing the workload of teachers and enhancing the educational experience of students. The report concludes with a discussion of possible technology solutions appropriate to suit the needs of the Mathru Center and a set of recommendations for the next iSTEP assistive technology research projects with the Mathru Center.

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Introduction

There are approximately 93 million children worldwide (i.e. approximately 1 in 20 of those aged 14 or younger) living with a moderate or severe disability of some kind [12]. This staggering statistic necessitates the development of assistive tools that can help sustain a healthy life for these children irrespective of their disabilities. In recent years technological advancements have spearheaded the development of innovative solutions to meet the needs and aspirations of disabled children. However, according to the World Health Organization, in many low-income countries only 5 - 15% of the people who need assistive technology are able to obtain it [12]. This is primarily due to the high cost involved in developing, procuring and maintaining such technologies in these regions of the world. Assistive technology is defined by the Technology-Related Assistance Act (Tech Act) of 1988 (P. L. 100–407), and the Individuals with Disabilities Act (IDEA) of 1990 (P. L. 101–476), as "any item, piece of equipment, or product system, whether acquired commercially off-the-shelf, modified, or customized, that is used to increase, maintain or improve the functional capabilities of individuals with disabilities."[5] There are two purposes of assistive technology. First, technology can augment an individual's strengths by counterbalancing the effects of a disability; and second, it can provide alternative methods for performing a task so that disabilities can be compensated for or bypassed entirely [5]. Several assistive technologies have been introduced to aid in day-to-day tasks (e.g. power chairs, screen readers, etc.), but there has also been a recent increase in emerging assistive educational technology, which can be used to support and enhance the learning environment for children with disabilities. To this end, the TechBridgeWorld (TBW) research group at Carnegie Mellon University (CMU) has partnered with the Mathru Educational Trust for the Blind (Mathru Trust) in Bangalore, India to develop economically feasible assistive technological solutions to educate students at The Mathru Center for Differently-Abled (Mathru Center). This center was newly developed by Mathru Trust to address the growing need for educational resources for children with multiple disabilities or challenges other than blindness.

The iSTEP (innovative Student Technology ExPerience) research internship was initiated by TBW to provide CMU students the opportunity to work on technology projects that to address needs of underserved communities. This report summarizes the comprehensive needs assessment undertaken at the Mathru Center by the iSTEP 2013 research intern team during the course of nine weeks in the field. The objective of this investigation was to determine if and how assistive technology can play a role in supporting and enhancing the center's educational and developmental goals for its students. This report discusses key findings from the field and highlights information pertaining to research methods employed to retrieve those findings. Researchers observed in-class student activities and assessed creative teaching strategies used by the teachers to meet the varying educational needs of students. Additional information was collected through interviews with teachers, staff and special educators, as well as participatory design experiments. This report concludes with recommendations for the next iSTEP program, and future research opportunities and technology projects at the Mathru Center.

Target Audience

This research project was undertaken at the Mathru Center, which currently has four teachers and 27 students. All students have varying levels and combinations of disabilities including hearing impairment, deafness, muteness, cognitive/mental disabilities, cerebral palsy and speech impediments. The objective of this study was to understand whether and how assistive technology can play a role in supporting and enhancing the learning and teaching experiences for students and teachers at the Mathru Center. Findings presented in this report are relevant to special educators, teachers and any other professionals or groups working with students with disabilities, particularly those at the Mathru Center. This work is also applicable to researchers and innovators working in the field of assistive technology, who focus on designing and developing tools for this population of students.

Contributions of this Work

The research project detailed in this report will help support and enhance the educational environment and experience for students with multiple disabilities. Research results presented here provide meaningful insight into the challenges associated with meeting the educational needs of students with varying types and combinations of disabilities. These findings also offer a better understanding of the kinds of assistive technologies that can be incorporated in the educational environment of such students. In addition, this research project provides insights that could influence educational practices at specialized institutions that cater to the educational needs of students with varying disabilities. Finally, the knowledge gained from this study could provide a basis for future work in the same field. In particular, these research findings will serve as foundational data for the next iSTEP research team who will be working on development of assistive technologies suitable for the Mathru Center.

Outline of Report

This research report begins with background information on TBW, the iSTEP internship, and the Mathru Center. Research methods are discussed next, with an outline of research objectives, a review of related work, and detailed information on the needs assessment conducted at the Mathru Center. In particular, this section includes a description of research participants, and a discussion of data-collection methods and outcomes of the study. In addition, this report surveys existing tools used at the Mathru Center and identifies any potential challenges that could be encountered when implementing new technologies. The report concludes with a discussion of possible technology solutions appropriate to suit the needs of the Mathru Center and a set of recommendations for the next iSTEP assistive technology research projects with the Mathru Center.

Background

TechBridgeWorld

TBW is a research group that builds partnerships with underserved communities internationally to create culturally appropriate technology that adheres to each community's vision of progress (Figure 1). Founded in 2004, TBW leads innovation and implementation of technology solutions to help address challenges in technologically underserved communities across the world. They invent new tools, customize existing technology, and inspire and train future researchers and technologists. Based at CMU, TechBridgeWorld employs the knowledge and imagination of faculty, staff and students in all of our projects.

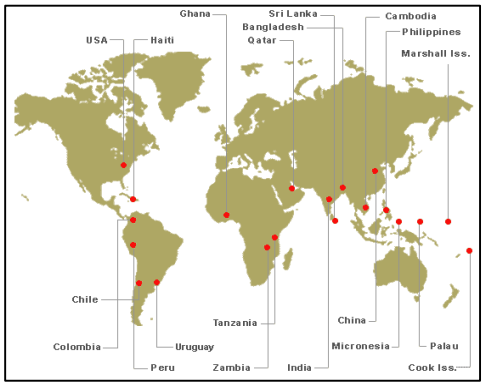

Figure 1. TechBridgeWorld's partnerships across the world

iSTEP

Figure 2. Image collage of past iSTEP teams (2009 – 2012)

TBW launched the iSTEP program in the summer of 2009 to provide CMU students a real-world, real-work experience in applying their knowledge and skills for creative problem solving in unfamiliar settings (Figure 2). iSTEP is a 10-week unique summer research internship that provides students with the opportunity to conduct technology research projects in underserved communities across the world. Both undergraduate and graduate students from CMU's Pittsburgh and Doha campuses are eligible to apply. Together with TBW, the iSTEP team collaborates with local partners to better understand the needs of the community and research technology solutions that could help address some of those challenges. The combined TBW and iSTEP teams are globally-distributed with iSTEP interns based in the overseas partner location and TBW faculty and staff based at CMU's Pittsburgh, USA campus. The iSTEP program is a very rigorous and competitive research internship program that attracts exceptional students who demonstrate high levels of creative problem-solving skills, academic achievement, teamwork ethics and cultural adaptability, and have a global mindset and broad outlook. Students selected for the iSTEP internship program gain valuable work experience through their work with underserved communities in various parts of the world. iSTEP 2013 interns worked on assistive technology projects in collaboration with the Mathru Educational Trust School for the Blind (Mathru Trust) located in Bangalore, India. The multidisciplinary iSTEP 2013 team comprised of a mix of undergraduate and graduate students and recent alumni from various schools at CMU including the School of Computer Science, Carnegie Institute of Technology, Tepper School of Business, College of Fine Arts and Mellon College of Science. Past iSTEP locations included Tanzania in 2009, Bangladesh in 2010, Uruguay in 2011 and Ghana in 2012 with projects in assistive technology, literacy tools, information exchange and environmental sustainability.

The Mathru Center for Differently-Abled

In 2001, Ms. Gubbi R. Muktha founded the Mathru Educational Trust for the Blind (Mathru Trust), which is an entity funded by private donors who support the education and development of blind children in India. That same year the Mathru Trust went on to establish the Mathru School for the Blind (Mathru School) in Bangalore, the largest city in the Indian state of Karnataka. The Mathru School is dedicated to the growth, education and care of visually impaired and blind children. After almost a decade of success with this school, the Mathru Trust sought to expand its reach through the development of a center to support students with multiple disabilities. The work described in this report was conducted at the new center for students with hearing impairments and multi-sensory disabilities.

Figure 3. Nandini

In the year 2010, the Mathru Trust initiated "Project Nandini" under the guidance of Sense International India (SSI). The motivation behind this new undertaking was the compelling story of a young, visually impaired student named Nandini (Figure 3). In 2006, Nandini enrolled at the Mathru School. She spent four years at this school learning braille and developing life skills along with her peers. In the summer of 2010, she contracted chicken pox. Her family lived in a rural and impoverished area of India and was unable to obtain necessary medical provisions to treat Nandini. As a result, she lost her hearing ability, and is now both visually and hearing impaired. Project Nandini was established to cater to the educational needs of students like Nandini, who have multiple disabilities.

Figure 4. Mathru Center for Differently-Abled

Under this project, in 2012 the Mathru Trust instituted a free, residential school entitled the "Mathru Center for Differently-Abled" (Mathru Center) to support the education and development of hearing impaired and multi-sensory disabled children. This new center is located in the Srinivasapura region, which is about six kilometers away from the Mathru School in Yelahanka (Figure 4). In addition to drawing inspiration from Nandini's story, the center was also set up primarily due to the fact that many of the visually-impaired students at the Mathru School also had other forms of disabilities such as hearing impairment, deafness, muteness, cognitive challenges, cerebral palsy and speech impediments. The focus of the Mathru Center is to provide students with an all-round education by supporting their social and emotional development, improving their communication, cognition and mobility skills, and enabling them to independently manage their day-to-day activities. In addition to its emphasis on education, the Mathru Center also hosts a range of different services for the community, including computer training and vocational support for rural women. The center's various activities are described below.

Free School for the Hearing Impaired and Multi-sensory Disabled Children

This school has qualified teachers and special educators who are trained in sign language and in meeting the educational needs of students with hearing impairments, as well as those with multi-sensory disabilities (Figure 5). The school also teaches students sports, yoga, painting and crafts.

Figure 5. Mathru Center class for multi-sensory disabled

Figure 6. Mathru Trust computer learning center

Free Computer Training Classes for Underprivileged Children

The Mathru Trust set up a computer lab with the help and support received from the TATA Consultancy group and a local group called *Prayukthi* (Figure 6). Basic computer lessons are offered free of charge to local underprivileged children from surrounding areas.

Teacher Training Program

The Community Based Rehabilitation (CBR) network across India collaborated with the Mathru Trust to provide quality education and training to teachers. In this regard, the Mathru Trust has been recognized as a CBR "Study Center" which not only provides free education to children with disabilities, but also provides training for teachers who educate these children (Figure 7).

Figure 7. Teacher training with CBR network

Manufacturing and Free Distribution of Sanitary Napkins and Leaf Plates

In 2012, the Mathru Trust began a production unit to make sanitary pads for the underprivileged girls and women in the surrounding areas (Figure 8). The Mathru Trust also initiated the manufacturing of leaf plates, which is a natural product made by local rural woman from surrounding areas (Figure 8). These leaf plates are then sold at the local market and provide a source of income for the women who create them.

Figure 8. Production facility for sanitary napkin (left) and leaf plate produced at the Mathru Center (right)

Needs Assessment

The focus of this research study was to conduct a thorough needs assessment with staff, teachers and students at the Mathru Center. To understand the needs of the Mathru Center, researchers followed the prescribed CMU Institutional Review Board (IRB) guidelines to interview teachers and staff, conduct observations of critical activities at the center both inside and outside classroom, elicit opinions of a local special education expert, and administer participatory design experiments with teachers and affinity matching with students.

Objectives

The objective of this research initiative was to understand whether and how assistive technology can be utilized to enhance the learning and teaching experiences of students and teachers at the Mathru Center. In particular, researchers observed and assessed ways in which students with hearing impairments and multi-sensory disabilities could be assisted in education through technology. This provided a better understanding of the current educational state of students at the Mathru Center including the needs of both teachers and students, and ways in which technology could be used to enhance the learning environment and outcomes for students. Based on data collected in this study, follow-up research can be pursued to develop tools to benefit the Mathru Center.

Related Work

To inform this research study, related work was surveyed to learn more about various methodologies and tools employed in the education of children who are diagnosed with the following disabilities: hearing impairment, deafblind condition, autism and cognitive challenges.

Education of Children with Disabilities

The different degrees of hearing loss (mild, moderate, severe, and profound) suggest that children with hearing impairments have different communication and educational needs **[3] [6]**. Moreover, any kind of educational endeavor related to a hearing impaired student needs to fully involve parents and immediate family members. According to Mukuria and Eleweke, a major argument for the active involvement of parents in the education of their children with hearing loss is that “95% of these children are born to hearing parents who have no previous experience and knowledge of raising a child with

hearing loss." **[3]** The active involvement of parents leads to better learning outcomes for the student. Mukuria and Eleweke state that the goal of early intervention from parents in the education of their child is to foster effective parent–child communication and to provide an opportunity to acquire language in the appropriate modality (sign or spoken). The fact that hearing impaired children are not able to listen to their own voice poses an additional challenge to the learning and acquisition of a language during the early stages of their development. There are three main avenues for the hearing impaired to access language: speech reading, hearing (for mild or moderate hearing impairment), and sign language **[6]**. Some may also employ a combination of these three methods, or techniques including visual cues and face-reading to communicate with others **[6, 10]**. There are some disadvantages associated with each technique. Most notably, only about 50% of English speech reading can be observed through lips while the other 50% is spoken behind closed lips, which does not facilitate the process of reading lips to understand what the speaker is trying to convey **[6]**.

In special educational institutions that cater to the needs of students with disabilities, educators often utilize visual aids to teach hearing impaired students. This same educational technique has also been observed at the Mathru Center. Through the use of images, hearing impaired students are better able to grasp concepts such as the names of the animals, different modes of transport, human body parts, etc. A number of studies pertaining to hearing impaired education consider visual aids to be a valuable educational tool. Because sign language is relied heavily upon to communicate, deaf students are frequently described as visual learners by their teachers, deaf individuals, and others **[1]**. Like reading, learning sign language is a verbal skill, even if it depends on vision rather than voice. Hence, a preference for sign over speech as the language of instruction is not sufficient to classify someone as a visual learner **[1]**. Therefore, it is important to assess hearing impaired students' visual-spatial abilities, in addition to their cognitive skills, prior to developing any kind of intervention to enhance their educational experience. Having a good understanding of spatial relations is particularly important for mastering mathematical concepts. For deaf students who have greater spatial relation skills, having access to diagrams representing conceptual and relational information within a math problem can facilitate their arriving at a solution **[1]**.

Special educators for primary classes often first teach students key concepts through reading and writing activities. Sign language is also used to explain those same concepts. According to Mukuria and Eleweke, "students use their knowledge and skills in their first language (signs) to learn literacy skills in their second language (English)." **[3]** Additionally, research related to the cognitive and metacognitive abilities of deaf learners, showed that deaf students tend to be less likely than their hearing peers to automatically utilize cognitive abilities and knowledge that they are known to have **[1]**. This indicates that lessons need to be planned in a manner such that the different learning needs of hearing impaired students are sufficiently met. According to Mukuria and Eleweke, planning must take into account the following requirements: "realistic diagnostic assessment of educational needs, instruction that focuses on specific needs, assessment of growth, and evaluation of instruction." **[3]**

The educational approach for a hearing impaired student is radically different from that applied to students who are deafblind, which is a condition indicating the presence of a dual sensory impairment, which involves the auditory and visual senses **[2]**. However, not every deafblind individual is either

completely deaf or completely blind **[11]**. Still, the impairment of both senses either partially or completely poses unique challenges in the education and language development of deafblind students. Each individual has five primary senses to express and receive stimuli from the environment. Out of these five, two of them are chiefly used: the visual and auditory senses. In the case of deafblind people, these senses are impaired and they have to therefore primarily depend on their sense of touch to interact with their environment. Touch and taste are close senses, giving information only about what is happening now, within arm's reach **[2, 11]**. The most widely used technique to directly teach distance to a deafblind student is the hand-under-hand approach that takes into account exploration with environmental objects **[11]**. Furthermore, the earliest technique ever used to teach language to a deafblind student involved finger spelling of the American Sign Language (ASL) alphabet in the palm of the student's hand. Using this hand alphabet technique, the student was taught words and concepts about her environment and the world **[2]**. Since most deafblind people have residual vision and/or hearing capabilities, appropriate educational techniques are used to align with and capitalize on that deafblind student's most optimal sense(s), including partial hearing and/or sight. These techniques include a combination of one or more of: (1) sign and body language, (2) hand gestures and (3) movements. In addition, "tactile senses are often used to explore environments and communicate" **[2] [11]**. For example, deafblind students who have less visual efficiency may primarily use the hand-over-hand approach or tactile mode of sign language. It is also important that the educational environment for deafblind students consist of a class order or a consistent class activity **[2]**. This entails establishing a specific order of class activities that enhances their learning. For instance, as the student enters his/her classroom, the student approaches a specific shelf that contains objects that represent activities that he/she will do during the day **[2]**. Other devices and techniques used in the education of deafblind students for communication purposes are: hearing aids, tactile signing, interpreting services, communication devices such as Tellatouch (a manual braille writer), braille reading, large-print reading, tactile communication cards, braille cards and cards with raised lines or images **[2]**.

In the case of autistic children, educational approaches should account for the following factors **[4]**:

- *Applied behavioral analysis*, which breaks tasks into small, manageable parts to achieve success
- *Structured teaching*, which implies providing visual and structural support to prevent failure
- *Relationship development*, which includes developing a positive and nurturing relationship with the autistic child
- *Social skills training*, which teaches appropriate social interactions through modeling, scripting, role-playing and the use of personalized stories

Research has also shown that approximately 70% of individuals with autism have intellectual disabilities; although more recent epidemiological studies state 40%. Furthermore, Dyches states "Some children with autism are highly verbal, while approximately 50 - 75% of autistic children have little or no functional speech." **[4]** There are several therapeutic tools and methods utilized to help enhance the speech and language of autistic children. These include speech training, augmentative and alternative communication, sign language, picture-based systems, and computerized communication devices **[4]**.

The Mathru Center enrolls students who demonstrate typical characteristics of individuals with cognitive disabilities. According to Bakken, these include: "short attention spans, problems with short-term memory, speech and language difficulties, deficiencies in generalizing information to new situations, challenges with motor skills, and low frustration tolerance, especially with regard to academic learning and abstract instructional activities." **[5]** To cater to the educational needs of students with cognitive disabilities, it is vital that the learning material presented to the student is in a group or a cluster form, rather than in a random order **[5]**. Educational techniques should also include practice with flashcards and pictures in addition to a repetition of the educational content **[5]**. Other methodologies that play a significant role in the education of students with cognitive disabilities include modeling, imitation, and learning through observation **[5]**.

Assistive Technology for Differently-Abled Students

Several computer-based applications exist for hearing impaired students. A research team based in Indonesia developed an Indonesian Sign Language Computer Application that is designed to assist people, especially children with hearing impairments to learn the Indonesian Language called Bahasa **[6]**. This application comes with six modules: (1) the "Dictionary Module" shows a sign language video or speech reading video of the word entered, (2) the "Picture Selection Module" allows users to create sentences in the Subject-Predicate-Object-Adverb (S-P-O-K) pattern using available pictures, (3) the Writing Sentence Module allows users to create sentences by typing words, (4) the "Free Sentence Module" allows teachers (and parents of children) to arrange sentences that are not affirmatives (e.g. questions, negative sentences, imperatives), (5) the "Finger Spelling Module" allows users to learn the finger spelling for a person's name or for words that do not have a sign language, and (6) the "Numeral Sign Mode" allows users to learn the numeral sign for numbers. This application can also serve as a digital dictionary for Bahasa Indonesian Sign Language for those that support sign language teaching [6].

Another internet-based application is the "SignOnOne," which teaches beginner-level English using sign language as the language of instruction **[7]**. This online course is comprised of 10 lessons on topics relevant to the Internet and the deaf. "SignOnOne" operates under the premise that English learning should begin with the written language taught using sign language. This application provides a visual representation of the content of each sentence instead of a direct translation of the text **[7]**. Additionally, it offers animations to further illustrate the substance of an English sentence. These animations are independent of any specific language, whether written or signed **[7]**.

Another available tool is a mobile-based application devised by a British research team. This application serves as a communication tool combining British sign language with gesture-based mobile communication technology **[8]**. The tool can translate sign language into text on a touch screen mobile phone, using a set of organized vocabularies integrated through gesture recognition technology **[8]**. IBM Corporation has developed a similar application called the ViaScribe **[9]**. This technology basically coverts voice into text and can be very useful for hearing impaired users. ViaScribe can also be used to transcribe speech or record speech in real-time during lectures or class session. There is also a visual dictionary designed to develop the reading and writing skills of hearing impaired students **[10]**. This dictionary currently contains a total of 235 images pertaining to frequently used words in an everyday

context. Visuals included in the dictionary were based on 1,500 words found in the sign language dictionary of the Ministry of Education in Turkey.

Notably, most existing assistive technology is applicable to visually or hearing impaired people, or those with a single, significant disability. There are very few, if any, tools available for those who have multi-sensory disabilities such as the deafblind. This study seeks to address this shortcoming through unveiling the needs of children with multiple disabilities, with the intention of informing future development of assistive tools to address these needs.

Research Methods

A variety of methods were employed to gain insight into the needs and challenges of teachers and students at the Mathru Center. These included observations, shadowing teachers, teacher interviews and participatory design methods including card sorting and an affinity matching exercise. These techniques are described below.

Observations

Researchers documented their observations across all classrooms at the Mathru Center. In addition, observations were conducted during special events and recreational activities at the center, in order to gain insight into students' social interactions and interests outside the classroom.

Shadowing

This is a contextual inquiry research method used to observe participants in their day-to-day environment. Researchers shadowed four teachers at the Mathru Center during the course of their work day to understand the students' and the teachers' daily schedule. This was done regularly over the course of the nine weeks. Shadowing enabled researchers to immerse themselves into the end user's environment, which allowed for in depth observation of classes and the typical behavior of students and teachers.

Interviews

Four teachers at the Mathru Center were interviewed. This included a new teacher who had extensive field experience working with hearing impaired students in rural India. Another one of the teachers had prior experience working specifically with students with multi-sensory disabilities. Teachers were interviewed individually and in-person in order to obtain detailed information on each teacher's unique experiences at the Mathru Center as well as at prior teaching appointments (Figure 9).

Figure 9. Researcher interviewing a teacher at the Mathru Center

Participatory Design Approach

For this aspect of the study researchers engaged teachers and older students from the Mathru Center in different activities through which they could indicate their preferences for teaching and learning. This included two activities for the students and one activity for the teachers.

For one activity, students and teachers were separately asked to sort a series of previously designed cards based on the difficulty level of the prompt. After the activity, answers and the difficulty rating provided by the teachers were noted and similarities across teachers were noted. Cards that had the maximum ratings were analyzed. A similar exercise was done with the students in the 2nd standard but the prompts provided to students to organize were relevant to their experience. This helped researchers understand which aspects of their teaching and learning experience are challenging for teachers and students, and also highlighted areas to focus on when developing assistive technologies for center.

In the second affinity matching activity for students, researchers provided participants with a set of pictures and asked them to indicate their affinity for the topic or subject by affixing a corresponding emoticon (expressing three different emotions: happy, sad or neutral) next to that image. Students were then asked to discuss with the researcher why they felt a certain way about specific subjects. This technique helped inspire students to consider subjects and topics that they would like to learn more about. This exercise was analyzed by providing numerical values to each of the "affinity" levels. For example, a smiley face was given a "+1" while a neutral face was given a "0" and a frowning face was given a "-1". Information collected through this activity helped researchers make recommendations for possible technology interventions that would appeal to the teacher and student population at the Mathru Center.

Participants

Participants in the research study included both teachers and students. A total of four teachers were involved in the research study. Three of the four teachers worked exclusively with the students with hearing impairments. One of the three teachers had prior experience in the field and was trained in Indian Sign Language, while the other two teachers were trained after their appointment. A special educator with extensive experience with students with multiple disabilities was also included in the research. All 33 of the students enrolled at the Mathru Center were included in the research study. There are currently four types of classes offered at the center:

(1) Multi-sensory class (MSI), which includes eight students with multi-sensory disabilities;
(2) 1st standard, which includes five students with hearing impairments;
(3) 2nd standard, which includes four students with hearing impairments and
(4) Nursery and Pre-Nursery, which includes 16 students with a range of disabilities:
    - Eight hearing impaired students;
    - Two students with both cerebral palsy and speech impediments;
    - Two students with both hearing impairments and learning disabilities;
    - Three students with cognitive challenges; and
    - One student with both a visual impairment and cognitive challenges.

Findings

In depth contextual inquiry at the Mathru Center through observations and shadowing teachers revealed the distinct needs of teachers who work with hearing impaired students versus those who work with students in the MSI class.

Teaching Methodology

Across all four classrooms in the Mathru Center teachers provide students with individual attention and rely heavily on physical or visual teaching aids such as models, flash cards, etc. Teachers engage students by showing them an image or object and repeating the names and features of what is displayed until students understand what it is. In addition, teachers often team up slow learners with faster learners so that students can learn from their peers. One teacher reported observing that students learn faster from each other rather than from a teacher. This observation was based on her experience at the Mathru Center as well as prior years of teaching at different institutions.

In classrooms with students with hearing impairments, teachers use flash cards to show students a visual representation of everyday items such as vegetables, fruit or furniture. Teachers then use finger spelling to spell out the name of the displayed object. At every step of this exercise, students repeat after the teacher. Teachers also teach students lip reading techniques before asking them to spell out the name of an object in English on the blackboard. This process is repeated multiple times with each student in the class and with each flash card or visual aid.

A similar process is employed by teachers in the MSI classroom, however the metrics they use to measure progress is different and the number of objects students learn about is limited to about three or four per lesson. Additionally, each student in the MSI class requires more individual teacher attention. For example, the student who is deafblind needs the teacher to communicate with her using tactile sign language, where the student feels the teacher's hand as she signs to understand what the teacher is saying to her. The student repeats after the teacher so the teacher knows if the student has understood what she is saying.

Survey of Teaching Tools

At the Mathru Center, teachers predominantly use flash cards as teaching aids. Some of these flash cards are embossed so that the students with vision impairments can interpret them through touch (Figure 10). Flash cards are also use to describe parts of human body, animals, trees and various objects such as a ball, table, etc (Figure 11). In addition to flash cards, teachers also use figurines of animals to describe them to hearing impaired students (Figure 12). Thus, the majority of lessons are taught using visual or tactile aids such as embossed flash cards, figurines, and charts.

Figure 10. An embossed alphabet card

Figure 11. Flash cards

Figure 12. Animal figurines

Identified Teacher Needs

Teacher interviews and the card sorting exercise helped shed some light on the needs of the teachers.

Time Management

This was identified as most difficult across all classrooms with three out of four teachers rating "time management" as one of the top three challenges during the card sorting exercise. Teachers mentioned that although they chart out what they have to cover during each class, they are rarely able to complete lessons as planned since they need to cater to the varying capabilities and needs of their students. The one teacher who did not rate time management as a top challenge later added that managing her time during class is a little difficult even though she accounts for the additional time it takes to complete the process of repeating everything until all students understand it.

Figure 13. Flash cards used by the teachers

Getting Appropriate Teacher Training

Teachers who came to the institution with no training believed that this was the most difficult aspect of their experience, but at the same time rated "learning sign language" as easy. Mastering sign language alone was insufficient to help manage their various work responsibilities, particularly given that these teachers had no prior formal training to work with students with hearing impairments.

Figure 14. Teachers working individually to organize the card by difficulty level

Additionally, teachers found it difficult to get access to appropriate training after joining the Mathru Center. Moreover, the instructor who originally trained them left the center during the 2013-2014 academic year.

Finding Resources to Help Teach Students

Two out of four teachers rated this as difficult during the card sorting activity (Figure 14). Teachers had different interpretations of teaching resources. One teacher interpreted them as trained professionals to help provide students with individual attention. Teachers who had not received formal, special education training interpreted them as books on sign language that they could refer to when needed. The one teacher who was trained in teaching hearing impaired students interpreted them as models (Figure 15) and flash cards (Figure 13). A notable observation was that teachers did not consider the technology, such as the Internet, a resource. This is possibly because they do not currently utilize such tools nor are trained to use them.

Figure 15. Models used by teachers as teaching aids

Engaging Students

Two out of four teachers found engaging students difficult, as they could not interact with all students at the same time. Teachers work with each student individually while the other students sit idly. Engaging students is particularly difficult in the MSI classroom, where students require more one-on-one attention given each of their very distinct needs and abilities.

Understanding the Needs of the Students

Overall, this was deemed the easiest task by teachers. They also found it easy to prepare classes based on student needs. Teachers create milestones for the entire class, every three months. In addition, every day they spend time summarizing their day in a daily report and planning their next classes. This process facilitates the task of preparing for classes.

Identified Student Needs

Most students at the Mathru Center are under the age of seven, and are still learning sign language and other forms of communication. Therefore, they were unable to directly articulate their needs and challenges. In order to gain insight into student needs, card sorting and affinity matching exercises were conducted with 2nd standard students while their teacher translated activity requirements to them.

Affinity Matching

Figure 16. Researcher explains the affinity matching exercise to a student

This activity was conceptualized to reduce the overhead of translating text to the students and to encourage them to interpret the activity any way they want to (Figure 16). Students unanimously rated geography, learning about animals and the solar system as the highest out of nine pictures representing different objects, professions and fields of study. Only one student was interested in the human body, but three out of four students were interested in doctors/medicine. While two students put smiley faces beside a picture of musicians, two others put frowning faces next to that image, explaining that they haven't experienced music.

Card Sorting

Although students initially tended to say they liked everything on the card, with the help if their teachers they were able to successfully complete the card sorting activity (Figure 17).

Overall, students rated "learning sign language" the most difficult task. Half the students reported that "learning science" was difficult, and a similar proportion found "learning English and Kannada" easy. Almost all students found it easy to converse with parents, although two students found "talking to classmates" difficult.

Figure 17. Cards given to Mathru Center student to organize by the level of difficulty

Recommendations for Future Work

Based on findings from this study, the following recommendations were made to facilitate and enhance the teaching and learning experiences of teachers and students at the Mathru Center.

Teacher Training Technology

Not all the teachers who are currently working at the school have an extensive background in working with children who are hearing impaired or have multi-sensory disabilities. Therefore, teachers experience a steep learning curve while on the job, and have to learn and adapt as they teach. Only one teacher at the school has an extensive background working with deaf students and sign language. She assists and teaches the other teachers when possible. However, this can be a burden.

Technology to assist in training new teachers on skills needed to work with students with various disabilities would be useful for the Mathru Center. Examples of useful tools include a digital library that can point teachers to available and pertinent online resources, and applications that offer them help with learning sign language, hand gestures for sounds and lip reading.

There are, however, some challenges to consider when developing such technology for teachers. One issue is that each teacher's base level experience and skills can vary significantly, so it could be challenging to establish tools that can cater to the various training needs of teachers. With regard to creating any sign language technology, the primary concern is that the sign language used at the Mathru Center is a local variation of Indian Sign Language and has no official dictionary to reference.

Therefore, developing a tool to teach this sign language could prove to be difficult. However, there is documentation that outlines the current process or general steps that the center takes to orient new teachers to this specific version of sign language. This information could facilitate the technology design, but periodic checks would still be necessary to ensure the technology content is up-to-date based on any changes the center may have made to their process for training teachers.

Lesson Planning Assistance

Teachers currently spend more than 20 minutes each weekday as well as over an hour during the weekend planning lessons based on timetables they previously established. In addition to this, they also spend time creating flash cards, buying other teaching aids such as animal figurines, and preparing other visual aids (e.g. drawings, charts, etc.) pertaining to concepts such as the human face and body. When planning is not completed during the designated time, teachers will either work during their lunch breaks or students' physical training classes. Providing teachers with tools to assist with the logistics of day-to-day planning would alleviate some of this burden on teachers. In addition, it could afford teachers the opportunity to explore new teaching techniques and tools, as well as focus on improving their teaching skills through training.

Automatically or electronically generating visual teaching aids (such as flash cards, drawings and charts) would be beneficial in terms of removing the need for teachers to create or shop for these items. Additionally, establishing a standard template for teacher timetables and possibly auto-generating these timetables each year could significantly cut down preparation time for teachers. However, there might be some challenges associated with creating and implementing such tools. For example, since timetables are specific to each unique class, it may be challenging to establish a standard template for these timetables. Furthermore, not all teachers follow a set pattern or style of teaching; therefore, tools to assist in lesson planning will need to suit a wide variety of needs and preferences of the teachers. Nevertheless, if such technology is implemented at the Mathru Center, this could reduce the time teachers spend planning lessons, creating timetables, and running errands to create and obtain classroom supplies and teaching aids.

Flash Card Generating Software

Flashcards are the most frequently used teaching aids at the Mathru Center, and teachers often have to create their own flashcards. This task takes up a significant amount of time and effort on the part of

teachers, but is necessary given how useful flashcards are to teaching students at the center. A computer program or device designed to generate customized flashcards could assist teachers in this endeavor, and reduce the amount of time and work they need to put into creating these visual aids. Additionally, such tools should be able to produce a broader variety and greater volume of flashcards for students to interact with.

Ideally, such technology would include a diverse image library along with a high quality search engine to match a word or phrase entered by the teacher to an appropriate image or list of images. Additionally, if the image library does not return any results for a particular search query, there should be an option for teachers to enter their own drawing or photo to correspond with the given word or phrase. These customized additions can then be reused by the teacher and will be accessible to other teachers as well. This tool should also offer the option of printing a hard copy of the flashcard or developing an electronic version of it for sighted students to interact with (e.g. on a computer or tablet). Thus, if teachers are able to create a set of flashcards under a specific topic, they could pass out a printed set of these flashcards to students or allow sighted students to browse through the cards in a virtual environment. The virtual component of the tool could also be useful for reviewing material with students and possibly testing them on various lessons. A more advanced application could allow for video representations of words and phrases. This might be particularly useful to students learning sign language as they could observe how to sign a word by watching a relevant video demonstration. The technology will need to incorporate separate user interfaces for teachers and students, where teachers can use the tool to customize flashcard sets for their students, and students can engage with the material created by their teacher. In addition, student data can be tracked by logging the information on a local machine, and if Internet connectivity is available sending it to a remote server for analysis.

Challenges associated with Internet access at the Mathru Center (and the Bangalore area, in general) could cause difficulties with developing this type of technology that may need to depend somewhat on online data and services. Additionally, incorporating any sign language related video or image content will be straddled with issues stemming from the fact that the center does not use a standardized language structure. Consequently, teachers would most likely need to record themselves signing various words and phrases; however, this task could be too daunting for teachers because it is not something they are accustomed to doing. Furthermore, in order for the virtual student interface component of the technology to work successfully it would need to be installed on a portable device such as a laptop or tablet. However, there is significant hesitation on the part of administrators at the center about the use of tablets, because of the fear that students would misuse those devices. Laptops could be a possible alternative, but there may still be resistance to putting any relatively expensive device directly in the hands of students. The additional cost to the center, in terms of obtaining these portable devices, should also be factored into consideration for such technology. Alternatively, creating a specialized, portable device specifically for flashcard generation could be prohibitively expensive or an impractical use of resources. Finally, frequent power outages experienced in Bangalore would affect the implementation of any technology that is reliant on the local electrical grid.

Computer Training

Students at the Mathru Center have often expressed interest in learning more about how to operate computers, and this type of education could certainly benefit them in the future. However, there currently is no computer instructor at the center who can cater to the special needs of students. Hiring a teacher to train students in computer literacy is challenging, particularly due to the limited number of qualified candidates. Therefore, there is a need for tools that can offer some guidance to students on how to work with computers. One possibility is to develop a computer program that provides students with foundational knowledge on how to interact with computers through step-by-step instructions or even a gaming platform. Most importantly, any such technology needs to take into consideration the different abilities of the unique student population at the Mathru Center. In fact, this will most likely be the most challenging aspect of technology development, since the user interface will need to account for students who cannot hear and are still learning to read. Finally, as with any electronics, any computer program could be disrupted by frequent power outages, and may also be susceptible to computer viruses that may infect the center's machines. Safeguards and backup software will need to be put in place to account for such issues.

Sign Language Dictionary

Students at the Mathru Center occasionally struggle with communicating with teachers using sign language. Also, when students go home they are often unable to use the sign language they learned in school to converse with their parents. Currently, a defined sign language dictionary for the signs that are used at the Mathru Deaf School does not exist. Similar to the Indonesian Sign Language Computer Application mentioned in the Related Work section of this report, a digital Sign Language Dictionary that captures that signs used at the Mathru Deaf School can help improve communication between students and teachers as well as their parents. The tool should allow teachers and students to create entries using video, which would capture them signing and/or fingerspelling the word. This tool also has the potential of helping new Mathru Center teachers learn the sign language used at the school. It is important that this tool allow teachers and students to maintain and update the database.

Speech Practice Software

Hearing impaired students at the Mathru Center spend a lot of time practicing how to sound out different syllables and words. As a group, students try to repeat (verbally) what their teacher as she guides them to make the correct sound. The teacher works with the entire class as well as with each student individually to assess their performance and try to correct them when necessary. However, this process is very time consuming and difficult. Technology to assist with this process might be useful both to teachers and students. The imagined solution could involve software in the form of a game which utilizes the microphone to hear whether or not the sounds students are making are correct. For example, students can practice volume, pitch, and enunciation. This would allow the teacher to attend to multiple students instead of one teacher at a time as the software can give the student visual cues and instructions.

Multi-sensory Classroom Assistant

The teacher for the MSI classroom at the Mathru Center frequently struggles to keep students engaged with different tasks. This class includes a deaf, blind and mute student, an autistic student, and mentally challenged students. Each student has unique needs and difficulties, and so creating exercises that are suitable for each child is challenging. Additionally, there is only one teacher and teaching assistant assigned to work with all students in the MSI class. Instructors need to keep track of what each student is working on at any given time, and try to ensure that all the children receive appropriate and timely feedback. This is a very challenging task that could potentially be facilitated through the application of appropriate technology.

This can be either a visual on a projector or an application on a tablet. The projector visual would almost be like an educational game/video (possibly even interactive using the Xbox Kinnect or something similar) that could display on the classroom wall. This would not only academically help the students but also possibly assist in physical therapy. An example of a game would be as follows. Two of several types of vegetables could be displayed on the wall from a projector. Students could stand in front of the projector and interactively reach to images and match liked vegetables by moving their arms to the vegetables in the air and direct in the direction where the second copy of the vegetable is. Overlapped vegetables make a successful pair. Many different types of interactive educational games can be made. Similar touch applications can be made on tablets for students.

Two main challenges arise. One is the age and maturity of the students. Tablets are expensive devices and younger or more challenged students might struggle to properly handle these devices. The other is the wide variety of different abilities of the students. The applications would need to be able to cater to several disabilities.

Evaluating Future Technology Projects at the Mathru Center

The main goal of this study was to assess the needs and challenges at the Mathru Center in order to lay the groundwork for future technology projects that would be undertaken at the center as part of the next iSTEP internship program. Findings from this study offer a rich set of data about the Mathru Center's students and teachers. However, prior to developing technology interventions for the center it will also be critical to look into any major changes that may have occurred during the time between this study and the intervention. Since this center is currently only two years old, it is still establishing itself and evolving. For example, next year the center plans to introduce a new class (3rd standard) and continue growing at a rate of one class per year. Additionally, there will inevitably be changes in the makeup and behavior of the student and teacher population at the center, so technology interventions will need to suit this updated user population. Once a technology has been implemented at the center, it will be important to monitor and evaluate this intervention to ascertain whether it is making the desired impact on students and teachers. Below are suggestions for aspects to consider when conducting such an assessment.

Baseline Data

Baseline data is important to any evaluation. Along with information collected from this study, data will continue to be collected by the TBW team after iSTEP 2013. This information should be useful to take into consideration when designing technology interventions for the Mathru Center and also when assessing outcomes from implementing those tools.

Potential Challenges to Data Collection

Potential challenges to data collection include:

1. Communicating with students to obtain either qualitative or quantitative data can be difficult.
2. Access to a qualified and reliable person to help translate information might be necessary if researchers and participants do not speak a common language. Locating such an individual to assist with translation might be challenging, especially in the case of sign language translations.
3. Given that all students at the center are minors, it is necessary to have a teacher or guardian present to help supervise and guide any testing with students. This too can pose difficulties, particularly in terms of scheduling testing sessions.

Possible Confounding Factors

Using a teacher to translate for the researcher can have both positive and negative consequences. Students are more comfortable and familiar with their teacher, which can be helpful in extracting more accurate information. At the same time, however, it is also possible that the teacher's presence will influence the student behavior and responses. Additionally, teachers may inadvertently bias their translations of student responses. Such biases and confounding factors will need to be taken into account when analyzing data.

Proposed Evaluation Strategies

Proposed evaluation strategies for each of the suggested technology interventions are given below.

1. **Training Teachers:** Document the current process or general steps the Mathru Center takes to orient a new teacher to the school and compare it with the equivalent process using the developed tool.
2. **Lesson Planning Assistance:** Maintain a folder or document in which, at the end of each session or the end of each week, teachers can note the time it took them to plan a lesson using the new tool. Compare this data with baseline information collected through this study.
3. **Flash Cards:** Measure the time students take to learn a particular concept, and capture any changes in grades and retention of information using the new technology.
4. **Computer Literacy:** Periodically test students on their performance of tasks taught via the computer literacy tool. Track changes in scores over time and also compare to a control group of students who do not interact with the technology.
5. **Sign Language Dictionary:** Whether or not the tool is capable of capturing all of the signs used at the Mathru Center and if Mathru Center staff can maintain the tool's database. Furthermore, the time it takes for teachers and students to learn the signs used at the school can provide insight into its effectiveness.

6. **Speech Practicing Helper:** Note if lecture time decreases because student is getting responses back quicker and adjusting voices faster. Also note if student's volume, pitch, enunciation improves as a result of the software. If a game is developed, measuring student engagement can provide insight into its effectiveness.
7. **Multi-sensory Classroom Assistant:** Measuring the time it takes the students to learn the related topics and measuring the overall satisfaction of the teacher who now will need to engage less students at any given time.

Conclusions

This assessment of the Mathru Center for Differently-Abled has helped derive a better understanding about the current state of its educational environment. Findings from this study provide valuable insight into the types of assistive technology that could address the needs of teachers and students at the Mathru Center. Researchers gathered a significant amount of data through interviewing teachers and staff, conducting observations of class activities, and administering participatory design experiments with teachers and affinity matching with students. Research results indicate that there are indeed possible technology interventions that could benefit the students and teachers at the Mathru Center through reducing the workload of teachers and enhancing the educational experience of students.

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