Using Networked Multimedia to Improve Academic Access for Deaf and Hard of Hearing Students

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Abstract

Deaf and hard of hearing students experience barriers that make access to mainstream universities a challenge. Educational technology has the potential to better include these students in the academic mainstream. This paper begins by outlining historical trends in education for deaf students because understanding the unique characteristics and experiences of members of the deaf community will be crucial for successful design. We then discuss current trends in educational technology in general, especially those that will ultimately be made accessible or compatible with the needs of deaf students. Finally, this paper describes the author's proposed thesis work: the development and evaluation of a classroom platform for deaf and hard of hearing students to access remote interpreters and captionists, avoid visual dispersion, and facilitate classroom interaction.

1. Introduction

Entering mainstream universities involves extra challenges for people who are deaf and hard of hearing: skilled sign language interpreters and captioners with advanced domain knowledge can be difficult to find; multiple visual channels of information in the classroom can be difficult to juggle; and collaboration inside and outside the classroom is often strained due to language barriers [28].

Classroom technology research aims to improve educational experiences for all students and this creates opportunities to better include deaf and hard of hearing students. Wireless networks, data projectors, and portable computing devices can be used to bring in remote interpreters, support the sharing and capture of instructional materials, and provide additional communication channels for everyone. A more digital academic environment creates an opportunity for customization to better suit the needs of individual students.

2. Goals and Contribution

This research will investigate and develop technology to help manage the many academic tasks required of the estimated 20,000 deaf and hard of hearing students at mainstream universities in the U.S. [38]. Development will parallel other educational technologies so that technology for deaf students will be similar to those used by all students. The DHH Cyber Community project at the University of Washington will be a catalyst bringing together video remote interpreter services, remote captionists, skilled interpreters, and knowledgeable people within the deaf community. The proposed work will utilize this web of resources and services and the high-bandwidth connections between them to promote the best educational environment and lower barriers to participation in university-level academics for deaf and hard of hearing students regardless of classroom type, instructor accommodation, or locally available resources.

3. Background

When designing for deaf and hard of hearing people, it is important to understand that as a group, they have extremely varied backgrounds and educational experiences. A person's self-identification as either deaf, hard of hearing, or hearing impaired is often primarily a personal choice and not a function of the degree and onset of hearing loss. Deaf people tend to prefer sign language, often choose not use their voice, and are likely to be involved in the signing Deaf Community (note the capital "D" indicating a sense of pride in the uniqueness of sign language and culture). Hard of hearing people tend to speak and lip-read and may rely on residual hearing, hearing aids, or cochlear implants when communicating with hearing people. They may also know sign language and participate in the Deaf Community. These groups are by no means distinct and both people and preferences can shift across group lines. Alternately, elderly people who have lost hearing later in life may better fit into a third group as they are unlikely to know sign language, do not identify with Deaf Culture, and may prefer the term hearing impaired (which is a term typically rejected by members of the Deaf Community as it is thought to negatively emphasize a deficiency).

The degree of a person's hearing loss is only a small aspect of their disability and does not necessarily determine the best classroom accessibility solution or accommodation. For some people, the ability to adjust the audio volume may be sufficient. For others, translation to a signed language may be more appropriate. For others still, access to text alternatives may be the best solution. For those who were raised in environments promoting speech training, good access to the face of the speaker may be sufficient. These different preferences are in large part due to varied backgrounds and personal experiences and no type of accommodation is perfect. Understanding the diversity of experiences from early childhood on is an important aspect of designing with and for deaf and hard of hearing students.

3.1. Issues Affecting Deaf and Hard of Hearing Students

From a strictly audiological point of view there are several ways to quantify hearing loss. The most common metric is the degree of loss in decibels (dB) from mild loss (25 to 40 dB) to profound loss (90 dB or greater). But, as the next sections will illustrate, hearing loss itself is only one of many factors affecting language acquisition and education of deaf students.

3.1.1. From Infancy to Early Childhood

There is a distinction between pre- and post-lingual deafness, meaning that deafness occurred before spoken language acquisition or after, respectively. Oral training (learning to speak and read lips) is much easier for post-lingually deaf children and much more difficult and often unsuccessful for pre-lingually deaf children. In either case, excellence at lip reading is not common.

Language acquisition depends much more strongly on early exposure to language, whether spoken or signed; relying on lip reading alone very much restricts the child's language exposure. In fact, deaf children born to deaf parents (much like hearing children born to hearing parents) experience almost effortless natural language acquisition simply through exposure to the language of their parents. However, ninety percent of deaf and hard of hearing children are born to hearing parents who do not know sign language. Many of these children are not exposed to any language in a natural way during those early critical years of language acquisition. Oral training is not a substitute for the almost effortless language acquisition that occurs naturally. This lack of early exposure to any language may be the reason that many deaf people struggle with the written form of spoken languages, for example English. In fact, for the lucky ten percent, early exposure to sign language and strong signing skills seem to act as a linguistic bridge to more easily acquiring English as a second language [31]. The effects of language acquisition during the early childhood years trickle through grade school, on to high school, and ultimately affect access to college and career.

3.1.2. From Early Childhood through Grade School

The type of schooling environment that a deaf student experiences growing up will also affect their preferred accommodation and access to the college classroom. Education for deaf children in the U.S. has undergone policy changes that have resulted in even more diversity within the deaf and hard of hearing group.

Until 1975, education of deaf children and adults in the United States was very centralized. Residential schools for the deaf were introduced in most states during the 1800s and Gallaudet University (an all-deaf liberal arts university) was founded in 1864. Centralization is based on the concept that deaf students need a specialized education because of their disability. In 1975 there was a fundamental change in public policy concerning the education of deaf people and others with disabilities with the passage of Public Law 94-142 now called the Individuals with Disabilities Education ACT (IDEA). The law mandated that all children with disabilities are assured a free appropriate public education. This "full inclusion movement" has not been without controversy [22]; some assert that a mainstream classroom may not be an ideal learning environment as it isolates students and reduces exposure to the deaf community and deaf role models. Since then, the percentage of deaf students attending residential schools has declined steadily to about 15% [45], with the majority attending mainstream schools.

3.1.3. From High School to College and Beyond

Although a large segment of deaf and hard of hearing students attend the three major universities serving primarily deaf students (Gallaudet, National Technical Institute for the Deaf (NTID), California State University Northridge (CSUN)), the vast majority of deaf students attend mainstream colleges and universities. According to the National Center for Education Statistics (NCES), over 20,000 deaf and hard of hearing students are enrolled in post-secondary educational institutions in the U.S., approximately 93% at the undergraduate level. This is likely an underestimate as the survey was conducted more than a decade ago, it did not include primarily deaf universities like Gallaudet, NTID, and CSUN, and not all students identify themselves to the university as deaf or hard of hearing. Over 50% of 2- and 4-year post-secondary institutes in the U.S. have identified as serving 1 or more deaf or hard of hearing student, nearly 95% for larger colleges and universities [38]. This illustrates how deaf and hard of hearing students are spread thinly at universities across the country, a point we will come back to later.

There are striking differences between classrooms geared toward all-deaf classes versus typical mainstream classrooms. All-deaf classrooms tend to be aligned in a semicircle so that all students can easily see the instructor, presentation, and all other students. Mainstream classrooms may have a number of different configurations, but the most frequent is rows of students all facing the front of the class (see Figure 1). Clearly, mainstream classrooms were not designed with the deaf student in mind.

a) Deaf Classroom at Gallaudet University (www.npr.org “At Gallaudet, a Turn Inward Opens New Worlds”)

b) Mainstream Classroom at Rochester Institute of Technology 9/2007 (interpreter far left, instructor front and center)

Figure 1: Deaf Classrooms as in a) focus on visual accessibility. Mainstream Classrooms as in b) are often arranged in rows.

Recent years have seen an increase in deaf and hard of hearing students attending mainstream universities, which is likely a result of the “full inclusion” movement, IDEA act, the Americans with Disabilities Act of 1990 that prohibits discrimination based on disability.

3.2. *Existing Accommodations*

This increase in deaf and hard of hearing students in the academic mainstream has resulted in an array of accommodations in academic settings including: interpreters, real-time captioners, hearing aids, FM systems, and note takers.

3.2.1. Interpreters

As more deaf students enter mainstream universities, there is a growing need for skilled sign language interpreters that have specialized, university-level knowledge and signing skills. Because deaf students are spread thinly across U.S. universities, matching a student interested in a given domain with an appropriate interpreter who has knowledge of that domain can be a challenge, especially for advanced courses and for universities serving only a small number of deaf students.

Video remote interpreting (VRI) has been used in the classroom to help increase resource opportunities for this matching problem. VRI uses an intermediary interpreter, not in the same room, who signs what is voiced and voices what is signed for deaf and hearing people from the within same room. Video relay services (VRS) have similar services and are very popular, but these services are restricted to telephone conversations between parties not physically co-located.

3.2.2. Real-time captioners

Communication Access Real-time Translation (CART) is the system used by court stenographers and closed captioners in both academic and non-academic settings to manually convert speech to text using a keyboard or stenographic machine.

Much like interpreters, real-time captioners can only effectively convey classroom content if they understand that content themselves. Thus, matching students with appropriate and knowledgeable captionists can also be a challenge. Remote CART can also be used where the operator receives the voice through a telephone or computer connection and the text is sent back over a data connection. Some CART systems allow the student to highlight and add their own comments to the real-time text as it scrolls across the computer monitor [41]. C-Print is a type of CART developed at the National Technical Institute for the Deaf that enables operators who are trained in academic situations to consolidate and better organize the text with the goal of creating an end result more like class notes and more conducive to study [17].

Several researchers are working on speech recognition for automatically displaying spoken language in text [5]. Error rates are slowly improving, but these systems have a long way to go until they are usable. Very low errors would be required as even the smallest error (imagine recognizing a "ought" when the speaker actually said "not") can completely change the meaning of the text. Using textbooks to train the system on relevant course content [27] can improve error rates. When these systems are used in the classroom, a human operator typically corrects the errors on-the-fly [49] and formats the text to show pauses to indicate speaker changes and to better facilitate later study. At this stage, the operator can not be eliminated altogether.

3.2.3. Note-takers

Because deaf students rely so heavily on visual communication, looking down to take notes causes them to miss the information that is being signed or captioned. Therefore, deaf students often receive notes from hearing students who volunteer (or sometime are employed by the university) to share their notes. Instructors may also copy class notes, slides, or transparencies for deaf students. While this helps ease visual burdens during class, the student may miss out on the value of taking and studying personal notes.

3.2.4. Accommodation of Choice

A student's choice of accommodation depends in large part on their experience and educational background: strength in sign language, comfort with English, and previous experience with a given accommodation. Studies that have compared different types of services (sign language instruction, sign language interpretation, CART, and C-Print) show mixed results, probably due to the diversity of student needs [32].

Additionally, the same student may choose different accommodations for different types of courses. As one student pointed out, real time text may be better than sign language interpretation for courses involving many new vocabulary terms: "C-Print works best in lecture-based courses and courses that rely more on words as opposed to formulas or graphics." [17]. Sign language may be better for courses such as geometry containing lots of spatial and relative information or for courses focused on discussion or debate if the student's preferred mode of communication is sign language.

Can too much accommodation be a bad thing? Mayer *et al*. showed that both real time text captioning and in-person sign language interpretation together resulted in greater loss of information than either one alone, perhaps due to visual overload [34]. In contrast, Marschark *et al.* found that having both sources of accommodation (but shown on the same computer screen) was beneficial [32]. Furthermore, students learned more from sign language during class but got more out of real time text notes for studying. This could indicate that more channels of information are in fact beneficial, but only if they are arranged in a way that reduces visual overload, a point we will come back to in Section 3.3.1.

3.3. Accessibility Goals and Design Criteria

In spite of the plethora of possible accommodations, attrition of deaf students at the university level is high. This is partly due to missed classroom information and underdeveloped study habits such as note taking, but it is also related to difficulty with social and cultural connections with other students [28]. Our work will address both missed information through visual dispersion and translation as well as issues with collaboration with other students.

3.3.1. Reducing Visual Dispersion

> "The ear tends to be lazy, craves the familiar, and is shocked by the unexpected; the eye, on the other hand, tends to be impatient, craves the novel and is bored by repetition." ~ W. H. Auden

Problem:
Unfortunately, there are several ways that a deaf student can miss classroom information. Because deaf students receive nearly all classroom information visually, they must juggle their visual attention between instructor, slides, interpreter and/or captioner, and personal notes or handouts. Due to this juggling, information can easily be missed. Even when best practices for classroom setup are followed such as reducing visual obstacles (having the student sit up front) and utilizing techniques to include deaf students, the visual juggling act still results in missed information [25].

Even if explicit information is carefully provided, inadequate access to subtler, implicit information may put students at a disadvantage. For example, both conscious and sub-conscious gestures used by instructors often contain task-relevant information that has been shown to be helpful to the learner in problem solving activities [19]. If deaf students' visual attention is focused on the interpreter or the captions, they may be missing out on this alternative mode of information. Having better visual access to the teacher and the ability to replay both the instructor's actions and the interpreter and/or captions later may further reduce missed content.

Visual distribution problems often found in the classroom are summarized nicely by the experiences of one profoundly deaf and profoundly influential researcher while enrolled in a workshop to learn a new statistical software package (from [31]):

> Superficially, the learning context seemed ideal: The lecturer was a sensitive individual who went to great lengths to ensure full access by deaf individuals participating in the workshop. He had a projection of his own computer display on a large screen behind him, and each participant had their own computer for hands-on activities. The sign language interpreters were the best that could be found: all experienced in interpreting under such conditions. The two deaf participants had strong backgrounds in the use of computers, research, and statistics. Yet, both quickly became lost, viewing the two days as a waste of time. What went wrong?
>
> Primarily the problem was one of multiple, visual tasks placing too many demands on the processing of information in the learning situation. While the hearing participants were able to look at their screens and listen to the presenter, the deaf participants had to look away from the interpreter to see the instructor's screen or to try a procedure on their own computer. Missing one sentence of the instructions was enough to slow down or even derail learning. Watching the interpreter made it difficult to catch each action of the presenter or the projected screen.

Key Challenges:
Consolidating visual content into one device may prevent missed information and reduce the visual juggling act. Laptops, tablets, webcams, and high bandwidth connections can all be used to consolidate and conglomerate the visually important

aspects of the classroom, making them easier to access. Regardless of the student's choice of accommodation and the source of that choice (whether the interpreter or captioner is physically present or remote) presenting it in one device along with the instructor, the presentation materials, personal annotations, and potentially other classmates will allow the student to make better use of their visual modality.

Consolidation will likely help since studies have shown that items located closer to a person's current visual task are more easily and accurately found than items located farther away in the periphery (the eccentricity effect). Wolfe *et al.* offer proof that visual attention is affected by eccentricity by showing that people are more likely to notice and quicker to locate nearer items. Also, the effects of eccentricity are reduced when there are fewer distractions on the screen [51]. We may be able to further reduce clutter by giving the user control over their interface to emphasize what is most important and cut out what is not, as in WinCuts [47].

A frequent question when talking about visual interfaces for deaf learners is if deafness has an effect on visual perception. While the visual modality is clearly important for deaf students, there is no evidence that deaf people are able to make better use of vision than hearing people [31]. However, in at least one study Corina *et al.* have shown that deaf students are better able to redirect attention from one spatial location to another and better able to detect important motion in their periphery [13]. This is especially impressive considering that deaf people watching sign language focus on the face of the signer over 95% of the time [10].

Empowering students to design their own layout and formatting on-the-fly will be important for supporting a diverse user group with diverse needs, but it may also offer insights into future user interface design for this group.

3.3.2. Broadening Opportunities for the Best Services

> "Teachers are the most important classroom 'technology' and students are the least utilized classroom 'resource.'"
> ~ Harold Johnson, Kent State University

Problem:
Deaf students can also miss information in the classroom if that information is not properly or accurately conveyed to them. Section 3.2.1 described the importance of matching students with interpreters and/or captioners who understand and can accurately interpret for advanced, university-level content. Because students are spread so thinly, finding appropriate interpreters and captionists can be a problem.

Key Challenges:
Using high-bandwidth connections and remote interpreters and captionists would increase the pool of available accommodation for a student to choose from. Several universities and companies including Viable Technologies [48] and HandsOn VRS [21] are already pooling their resources and offering services for this type of remote assistance in the classroom. This has been especially important in the recent past for remote schools and colleges that otherwise would not have the resources to offer this type of assistance [18]. Also, the Media Access Group at

WGBH provides real-time captions for live Web events and Web conferencing [35], which could be used for online courses. Remote accommodation has also been shown to be adequate for both real-time captioning and sign language interpreting as video-based interpreting appears to be just as effective as in-person interpreting [33]. Because the system will be flexible with students' choice of accommodation, they could potential choose an automatic speech recognition system, assuming error rates were tolerable and alternate accommodation was not available [40].

Better collaboration through the existing high-bandwidth connections between universities would allow better access to skilled interpreters familiar with specialized, university-level topics. The DHH Cyber Community project is already pooling together these types of resources. This approach will also allow different types of students to receive differing accommodations based on preference. For example, one student may prefer a remote sign language interpreter while another student prefers real-time captioning.

Relying on high-bandwidth connections may not always be an option and anytime a technology can use less bandwidth, it will be available more of the time. Our MobileASL group has developed compression techniques specific to sign language that may help reduce bandwidth usage [11]. Finally, the digital nature of videos will also have the benefit of being recorded, archived and perhaps distributed.

3.3.3. Reducing Barriers to Classroom Participation

> "Tell me and I will forget;
> show me and I may remember;
> involve me and I will understand."
> ~ Chinese proverb

Problem:
Communication, and thus participation, in the classroom can be strained for deaf and hard of hearing students due to language barriers. Plus, events outside the classroom (project group meetings and impromptu study groups) where there is no scheduled interpreter can inadvertently exclude deaf or hard of hearing students.

By the time students reach college, they are a diverse group with diverse backgrounds, knowledge, and communication/accommodation preferences. Mainstreamed students who may not have sign language skills and/or knowledge of deaf culture can feel excluded from other deaf students and sometimes stereotyped by hearing students [26]. This may further increase barriers to participation, which is crucial to academic success. A study of multimedia learning environments found that nothing affected learning more than student participation [14]. The study tested text only, text and content movies, text and sign movies, text and discussion questions, and all of these together. The only conditions to significantly affect learning were the ones involving discussion questions. Clearly, students do not learn nearly as much if they do not participate and interact in their own learning.

Key Challenges:
Deaf students may benefit from technological environments that put more students on equal footing. In fact, Richardson *et al.* found that the effects of hearing loss on

participation in distance learning courses was slight, perhaps because the asynchronous textual modalities of communication lowered the barrier to participation [43]. New "digital" classroom environments may have a similar effect, opening up new possibilities for promoting equality *within* the classroom.

3.3.4. Enabling Instructor Participation (buy-in):

> "Teachers open the door, but you must enter by yourself."
> ~ Chinese Proverb

Problem:
Instructors do not like to trouble shoot during class-time so the platform should work seamlessly with or without other technologies being used.

Key Challenges:
While the proposed technology will likely be beneficial for a wide range of classroom, meeting, study group, and other academic situations, we are primarily focusing on lecture-style classrooms for a number of reasons. First, enabling access to the most common type of pedagogy found in large university courses will make the biggest impact for deaf and hard of hearing students pursuing degrees at mainstream universities. Second, we feel that if we were to require a different type of pedagogy, use of the system would be reduced. Instructors should be able to teach in a way that is most effective for them and deaf students should be able to take any class they like, regardless of the teaching style or compliance of the instructor. Minimizing the burden on the instructor and placing more of the power and choice with the student will not only increase adoption of the technology, but will empower and increase opportunities for the student.

To summarize, people with hearing loss form a disability group very different from other disability groups. Accommodation needs can range from sign language interpretation to visual access to the speaker to text captions to FM systems and hearing aids. Clearly, a one-size-fits-all approach has a good chance of failure as different solutions will work for different students (perhaps even for different classes or situations) and flexibility and user choice will be key to adoption.

4. Related Work

Work related to the proposed technology can be divided into technology designed for typical mainstream audiences and technology designed specifically for deaf audiences, whether in the mainstream or deaf classroom.

4.1. Educational Technology (in general)

Classroom technology research aims to enhance educational experiences for all students by using technology to better engage and involve students in the classroom through active learning. Insights from this field will be incorporated into our project to better include deaf and hard of hearing students.

Electronic classroom response systems (CRSs) allow instructors to solicit feedback and results from student activities, and receive them electronically to then summarize or discuss as a class. These systems have been shown to have positive effects on classroom participation, active learning, and conceptual understanding [23]. They also tend to encourage shy or less outspoken students to contribute more and reduce the impact of students who tend to dominate classroom interaction [39]. "Clicker" systems are a subset of CRSs that allow students to submit short responses to the instructor (such as answers to multiple choice questions or numeric answers) so that the instructor can display summaries of class responses and opinions of students [12][16][20][44] or groups of students [15]. The summaries can serve as feedback on class understanding for the instructor and can spark conversation about a given topic, but they limit students in the type of their submissions and don't allow for anonymous, independent questions.

Systems that allow text and digital ink to be submitted to the instructor are less restrictive and better at promoting self-initiated dialog between students and instructor. The University of Washington's Classroom Presenter uses networked Tablet PCs to allow students to electronically submit work, questions, and/or comments to the instructor who can then choose to display submissions and digital ink on lecture slides [2][30]. Ubiquitous Presenter [50] and DyKnow [6] offer similar functionality, but with a web-based interface that requires no tablet (a laptop will do). In addition to submitting questions anonymously during class, ActiveClass allows students to rate the questions of other students to bring them to the attention of the instructor [42]. Because cost barriers exist to providing all students with similar technology, Classroom Presenter also offers a version using mobile phones, a device more and more students tend to already have [29].

The digital classroom has incredible potential to better accommodate the needs of students with disabilities in mainstream university classrooms. For example, LiveNotes uses digital ink over lecture slides to encourage group conversations and cooperative note-taking during lectures [24]. This type of interaction may allow deaf students to become more involved in the note-taking process without being solely responsible for their own notes.

As academic environments become more digital, capture and retrieval introduce interesting areas to improve content accessibility. Synchronization of video feeds, digital ink, and presentation materials could result in better preservation and easier post-class access, much like eClass [8] and other classroom capture techniques [37]. One might think that classroom capture would encourage students to skip class but studies suggest that it does not. In fact, in one instance students were more likely to attend if the class was being captured. Students tend to recognize the value of interactions that occur in an in-person group class [8], which helps to relieve the worry of missing class. As deaf students juggle their visual attention during class time, the ability to re-watch parts of the class that were missed may level the playing field and ease information retention.

4.2. Educational Technology for Deaf and Hard of Hearing

Both educational technology for deaf and hard of hearing students and educational technology for a general audience are developed to encourage participation and active learning. The focus of the former is typically more on translation of speech, new interaction techniques, and eliminating visual overload.

Networking within the classroom is also utilized in educational technology for deaf and hard of hearing classrooms. Linda Burik at NTID has shown active learning benefits from using wireless laptops and a SMART board in the classroom [9]. In her system, the teacher can show the students' work on the big class display for discussion, somewhat like Classroom Presenter but the instructor can "grab" student screens rather than receiving students "submissions." Students keep both their own digital work and digital copies of the instructor's notes so that participation in class and note-taking activities are one in the same.

Researchers such as Donald Beil have recognized the potential of using tablets in class to enable deaf students to take notes on top of, instead of away from, other classroom content [4]. Digital pen-based environments create further opportunities for deaf students in terms of self-notetaking as was proposed by Miller *et al.* using transparent video and overlaid digital ink to reduce the visual distance from the interpreter (video) and the student's notes (digital ink) [31].

In online distance learning settings, high-bandwidth connections and streaming video are already being used to better include deaf and hard of hearing students [7]. While this use of the technology works well for distance learning, we predict that the same benefits of inclusion will occur in the physical classroom as well.

To facilitate communication between deaf and hearing students in his classes, Jonathan Schull proposed a system that he successfully uses at RIT/NTID for students to join a common, on-the-fly chat room and display text concurrently to best augment a face-to-face conversation.

4.3. Enabling Technology (a comparison)

ConferenceXP [3] and Adobe Connect [1] are two conferencing technologies that have potential for use in our work. Both enable video/audio conferencing and remote sharing of presentation slides, application windows, and even entire desktops. We will leverage their existence and stability as a foundation for our own work.

ConferenceXP, developed at Microsoft Research, provides the infrastructure for networking the Tablet PCs used in Classroom Presenter and is also used for audio and video distance learning and classroom capture. Classroom Presenter is currently used by at least 70 instructors at universities nationwide and this number is likely to grow in the future, so compatibility would ensure that the technology used by deaf and hard of hearing students will work well in conjunction with the classroom technology used by all students.

Adobe's Connect also offers video and presentation conferencing technology that could serve as a backbone for remote connections with interpreters and captioners and sharing of in-class resources [1]. In fact, Adobe currently has an alliance with Caption Colorado (www.CaptionColorado.com) and WGBH (www.wgbh.org) to provide captions for meetings. Several universities in the U.S. are currently using Connect for remote, online distance learning. Its use as a distance-learning tool ensures that several of the components needed for in-class involvement and participation will be available.

Both ConferenceXP and Connect have released open source versions of their systems that would allow us to make the necessary enhancements needed by deaf and hard of hearing students, discussed in Section 5.

We will also leverage the high-bandwidth, reliable internet connections that exist between universities enabled through Internet2 and Cyber-infrastructure communities to provide the best quality video/audio and stable transmission.

Describing our planned use of these systems is best illustrated with a scenario. The following three scenarios are intended to convey different types of students, accommodation needs, class structures, and enabling technologies.

4.3.1. Scenario A (Connect, Remote Interpreter)

Sally is a deaf student at the University of Io. She is fourth-generation deaf and prefers to converse in American Sign Language. She is majoring in Psychology and taking Child Psychology 101. The class is discussion-based; the instructor tends to show slides and videos and then expects students to discuss their opinions about them. For this class, Sally is using Adobe Connect to bring in a remote interpreter from a different university who happens to hold a degree in Child Psychology.

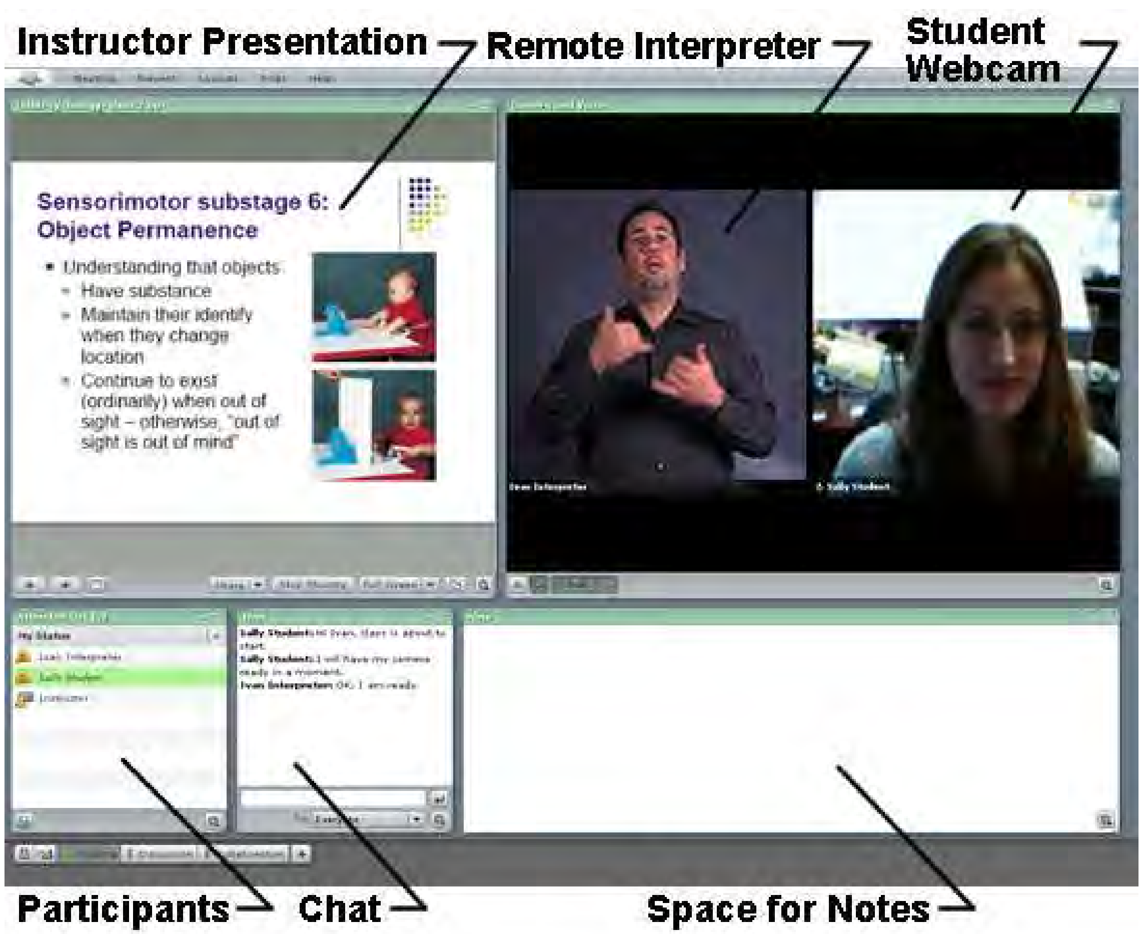

Figure 2: Using Adobe's Connect in Scenario A. Sally's computer screen show's the instructor's presentation, her remote sign language interpreter,

her own webcam, and the ability to chat and take notes.
The instructor has agreed to upload his slides and videos before classes start and to use the system during class. Because he only uses the power-point feature to show slides and videos, it is nearly the same process he would have used to teach (in fact he is even using the same materials as last quarter). The only noticeable different in class is that he now wears a microphone and earpiece to transmit voice between him and the interpreter. The students pass a microphone around during discussion and the instructor appreciates this added structure and enforced turn-taking.

Figure 2 shows Sally's screen on her laptop at the beginning of class. She has access to the instructor's slides and videos which are synchronized with his presentation. She can see both her interpreter and herself. She can chat with the interpreter and the instructor (if he checks the chat log) for example, incase the video stops working. And she has space to take typed notes. If she has a question or takes a turn in discussion, she signs to the interpreter who then voices for her. For this class, she chooses to turn the volume up on her laptop because the class is small and everyone can hear the interpreter. For larger classes, she would have the instructor repeat what he or she hears in their earpiece.

4.3.2. Scenario B (Classroom Presenter, Remote Captionist)

Bobby is a hard of hearing student at the University of Ganymede. He is majoring in Computer Science and currently taking Data Structures. He has only recently learned sign language (since he started college), so he does not yet feel comfortable with an interpreter. He prefers to use his voice to communicate and uses real-time captions during class because there are so many different vocabulary terms and acronyms in Computer Science courses and seeing the words helps him to find the topics later. He uses a note-taker because, in addition to the captions, he must watch the instructor who often writes code on the screen. Bobby has chosen ConferenceXP as a way to connect with his favorite captionist who is also a computer geek and so understands the content and is occasionally creative with ASCII art.

Luckily, his Data Structures instructor this quarter is using Classroom Presenter, so it will be easy for him to link the ConferenceXP connection he needs. All the students in class have TablePCs and submit in-class activities with digital ink. He too can create submissions and this puts him on the same level as other students. The use of tablets also gives him direct access to the notes of his note-taker. This enables him to add to the notes if he wants, but it mainly helps him refer back to the notes later because he sees them as they are created. The appearance of his screen can be seen in Figure 3.

From the instructor's perspective, her teaching process is exactly the same. She simply wears a microphone for the captionist and tells Bobby which session to connect to so that his tablet is on the same network as all the other tablets. Bobby then gives this information to his captionist, so that he too can see the slides. Instead of walking around the room with a microphone, the instructor prefers to repeat questions asked by hearing students as she feels this is a good practice to make sure all the other students heard the question.

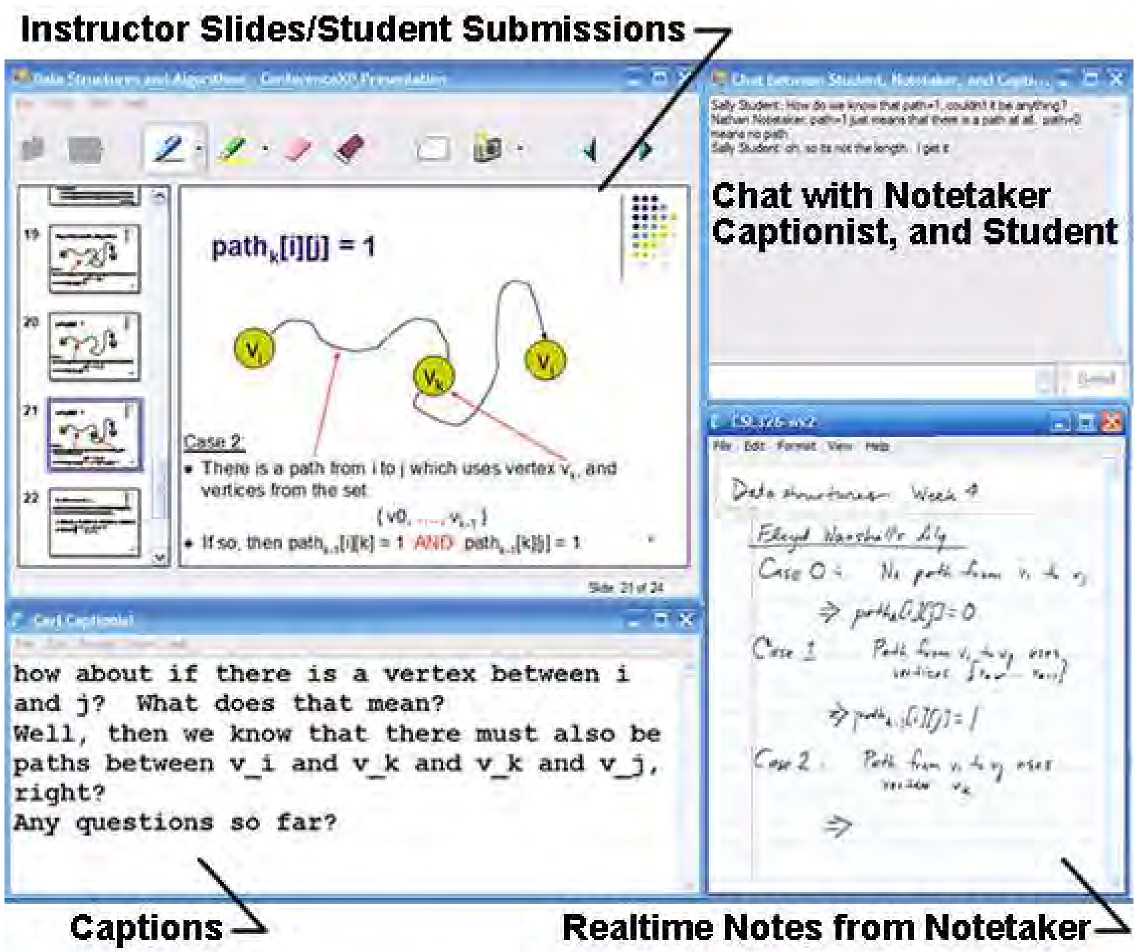

Figure 3: Using ConferenceXP in Scenario B. Bobby has the same level of involvement as all other students as they all submit activities with digital ink. He has access to a remote captioner and the digital notes created by his note-taker in class. He can chat with both his captioner and note-taker.

4.3.3. Scenario C (Interpreter in Class, Either Technology)

Tom is a deaf student at the University of Callisto and has attended mainstream schools from Kindergarten through high school. He prefers sign language interpreters and is accustomed to using them in class. This quarter, he is taking Intro to Biology in a huge, stadium-seating classroom. Even if he sits at the front of the class, the projected presentation is so large that he feels as though he is watching a tennis match between the screen, the instructor, and his interpreter. Instead, he sits a few rows back and uses a webcam to capture the entire front of the class. Then, he cuts out the important pieces: the instructor, presentation, and interpreter. He arranges these components on his screen so that he still has room for a chat window with a friend in class and a section for his own notes. Because the interpreter is present in the class with him, he can easily raise his hand, ask questions and interact.

5. Thesis Proposal

Existing technology has potential to alleviate some of barriers to and encourage participation in mainstream university-level academics for deaf and hard of hearing students. Designing, implementing, and evaluating technological solutions that bring many different technical and human resources into the classroom in an accessible and unobtrusive way is a challenging research problem. Technology has been shown to enhance education in the classroom and these "digital" environments open up new possibilities for leveling the academic playing field for deaf and hard of hearing students.

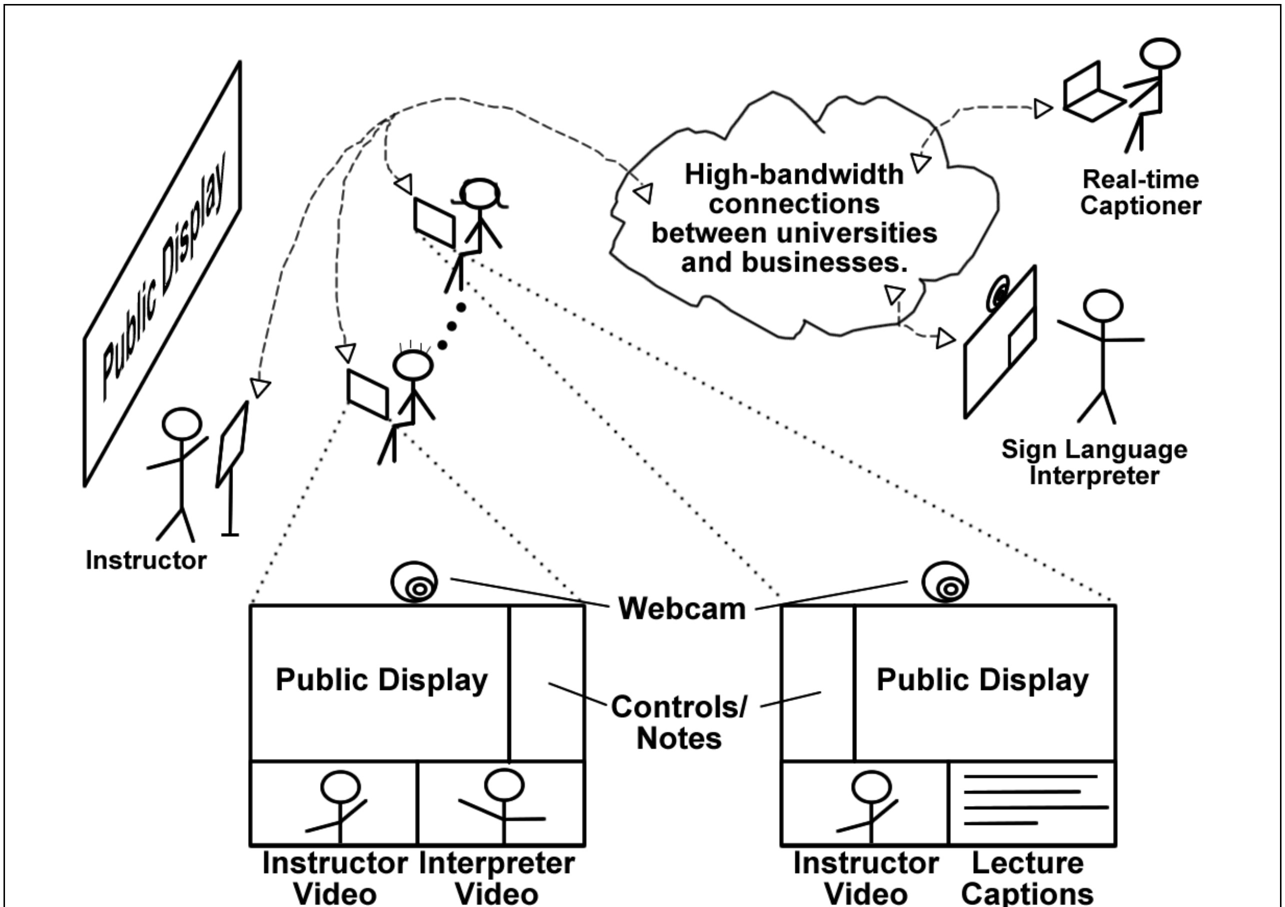

Figure 4: Networked multimedia brings remote interpreters and captioners into the classroom. Students have access to presentation, instructor, accommodation of choice, and their own notes. The instructor uses a microphone and earpiece and to relays audio, video, and presentation materials to the remote interpreter. Students' webcams relay questions and discussions through the interpreter to the rest of the class.

We will investigate effective ways for leveraging collaboration technologies for enhancing the participation of deaf and hard of hearing students in academic settings. The University of Washington's Classroom Presenter [2], Conference XP [3], and Adobe's Connect [1] will serve as a backbone so that technology for deaf students will be similar to and compatible with future classroom technology for all students. This technology will also be used to bridge the cultural and language gap between hearing and deaf students and encourage group work using text and digital ink. Given the scenario where all students are equipped with a networked Tablet PC, an additional opportunity exists for student collaboration. Finally, capture and retrieval introduce interesting areas to improve content accessibility. Synchronization of video feeds, digital ink, and presentation materials could result in better preservation and easier post-class access.

5.1. Enabling User Control of the Interface

Different accommodations will be required for different students, different classroom situations, and various aspects of the classroom will be more or less visually important for different students at different times. Flexibility in the interface will be crucial for success. We will modify existing video conferencing and classroom technology to enable students to choose the size and visual importance of each interface component. Using techniques like those found in WinCuts [47] and Facetop Tablet [36], our interface will allow students to crop, zoom, show, hide, and arrange independently, all while maintaining compatibility with technology used by other students and the instructor. To help reduce clutter on the screen, students may choose levels of transparency for videos feeds and other desktop components so that overlap can occur when appropriate. Imagine an interpreter standing to the left of a public display. She occasionally references specific items from the display as the instructor is talking about them. The student may want to reduce his video feed of the interpreter to show only her signing box (upper body from waist to the top of her head) and it will be important that her video feed appears to the left of the video feed showing the public display. No interface could be expected to predict these types of scenarios and students preferences. The best solution will be to engage the student in the creation of their own academic environment in a way that adds minimal complexity to the interface.

5.2. Enabling Collaboration and Group Work

Communication, participation, and active learning in the classroom have all been shown to promote learning in positive ways. These types of activities can be difficult for deaf students due to language barrier and interpreter/captioner delay. Compatibility with other classroom technologies, such as Classroom Presenter, will assist with this. The ability to anonymously submit questions and answers to the instructor is likely to play a role in reducing barriers to participation.

Additionally, we will develop mechanisms to create or access alternate channels of communication if they are available. If students in the classroom have digital-ink-based devices, students will be able to share notes much like LiveNotes [24]. Students will be able to connect to synchronous text chat channels for discussion much like in the classrooms of Schull [46]. If the deaf student has arranged to have a note-taker, the two could combine efforts by having access to the digital ink or text notes being created on-the-fly.

5.3. Enabling Capture and Later Retrieval

Because deaf students have a multitude of priorities that divide their visual attention during class, having access to a captured version of that class for review may help them to fill in missed content and parse class notes.

We will create an online repository for classroom capture if the student chooses this option. Mechanisms for both student and instructor security will be explored. We will borrow some of the tried and true techniques from eClass [8] for implementing segmentation of the recordings. For example, slide changes are a natural way to segment the video and allow students to easily access the interval of the class they are interested in. We will also explore techniques for allowing students to mark their own points of interest for later retrieval during class.

5.4. Evaluation Techniques

Evaluation of the proposed classroom technology will be an integral aspect of the project from day one. Involvement from the deaf and hard of hearing community is key to adoption, so evaluation will take the form of focus groups, participatory design techniques, and iterative design where feedback from students is incorporated into the design at every iteration.

However, implementing traditional HCI techniques of evaluation will be difficult due to a limited number of diverse users, inconsistencies in instructors' teaching style, and technology and classroom setup. Doing studies with sustained use over several courses and several students will be impractical. For example, it would be difficult to teach the same course with and without the proposed technology because comparisons may not easily be made across a small handful of students.

Some of the most successful and influential work in the field of educational technology has studied the effects of learning, scores, participation, and student responses to questionnaires and interviews across hundreds of students and tens of years [8][24]. Interestingly, none of the studies were able to find significant results from the collections of attendance and grades (two data points that would be difficult for us to use reliably). Even 33 years of research on electronic response systems yields inconclusive results on effects of academic success, citing pedagogical practices of the instructor among other things as dominating factors [23]. The most significant and meaningful results from these studies were obtained through student questionnaires, surveys, and observations of student behavior.

Student surveys, focus groups, student and instructor artifacts, observational interviews with both instructors and students that focus on student perceived benefits seem to be the norm [6][15][20][30]. Learning improvements, test scores, and grades may not be reliable measures because evaluations "in the wild" in actual classrooms will have too many confounding factors, including variability of students, instructor's teaching style and level of engagement, participation of other students in the class, time of day, and lecture topic. Cost/*benefit* analyses may be more practical than cost/*effective* analyses and may even result in better indicators of quality of learning and interaction with instructors and peers. Thus, we will measure impacts on classroom environment, participation rates, and subjective measures based on student perceptions.

Evaluations for the project will test the following hypotheses.
Potential Hypotheses:

1. Students will feel that using the technology in class makes lectures more engaging.
2. Students will feel they have learned more as a result of using the technology.
3. Students will participate more in classrooms when using the technology.
4. Students will feel they participate more as a result of using the technology in the classroom.
5. Students will feel that the quality of their interaction in the classrooms is improved when using the technology.
6. Some students will alter their seating behavior as they are no longer forced to sit at the front of the class.
7. Students will view the technology as a useful study tool.
8. A majority of students will voluntarily continue to use the technology after participating in the study.

In addition to these hypotheses, we will also include evaluations for some of the adverse effects that we hope to avoid or outweigh with our technology, including 1) a learning curve for the technology that distracts from learning course content, 2) in-class distractions caused by the technology, 3) increased potential for off-topic behavior. Although we should decide carefully if any effects from point 3) are in fact adverse. In light of research that suggests that attrition of deaf students is partly due to isolation, increases in communication, even if off-topic, may have more of a positive than a negative effect.

During evaluations, we will collect the following types of data. We will collect quantitative data from recording student interactions and observing student and instructor behaviors. We will also collect qualitative data from focus groups, student survey, interviews, and voluntary student feedback.

Quantitative data:

- Attendance and/or classroom participation
- Effects on note-taking behavior.
- Effects on seating behavior.
- Increased or continued use (even without study requirements) would likely imply that students see the technology as valuable.

Qualitative data:

- Students' self-reflections on access to classroom content, note-taking behavior, participation, performance, learning experience and feeling of inclusion.
- Effects of classroom engagement.
- Students' perception of the technology as a useful in-class tool.
- Students' perception of the technology as a useful study tool.

We are currently collaborating with Rochester Institute of Technology (RIT), home of the National Technical Institute for the Deaf (NTID) supporting over 400 deaf students in the academic mainstream, over 120 sign language interpreters, and over 50 captioners. Evaluation of the technology will take place in mainstream classrooms at the University of Washington using both technical and human resources at RIT.

Another excellent opportunity for evaluation and feedback is the Summer Academy for Deaf and Hard of Hearing Students hosted each summer at the University of Washington. The top ten deaf college freshmen or sophomore applicants join the program to take college courses focused on introductory Java programming, computer science, and related fields. Because the academy involves mainstream courses, it presents an ideal testbed situation. Students who are interested in participating will be asked to use the technology, including a remote sign language interpreter or captioner, during class time and rate its usefulness through a series of questionnaires. Weekly one-on-one interviews will be conducted to discuss problems, suggestions, and other feedback.

5.5. Timeline

Spring 2008

- Prepare a working prototype of the classroom technology for the DHH Cyber Community Summit gathering in June 2008.

Summer 2008

- Implement and evaluate an initial version of the classroom technology locally at the University of Washington.
    i. This version will be fully functional, but may not include all of the desired features, such as capture.
- Conduct evaluations with students from the Summer Academy for Deaf and Hard of Hearing.

Fall 2008

- Use feedback from the summer release to improve the design of the system.
- Create an online repository for capture and retrieval.
- Implement and evaluate the classroom technology with interpreters and captioners at RIT and students at UW.
- Execute a formal user study to determine the best digital educational environment using the classroom technology.

Winter 2009

- Iterate improvements to the system based on the results from the formal user study.

Spring 2009

- Continue to improve and develop.
- Begin longitudinal studies with UW students to investigate long term use and results of any novelty factors.

Summer 2009

- Release and evaluate at Summer Academy for Deaf and Hard of Hearing and compare results to previous summer academy.

Fall 2010

- Finish remaining analysis and research.
- Prepare dissertation and defend.

6. Conclusion

Our primary research goal is to find ways to increase involvement of deaf and hard of hearing students in university academics. With this goal in mind, we will strive to broaden the accommodation resources for students through high-bandwidth remote interpreting, reduce the visual dispersion of important in-class components through on-screen consolidation, and encourage in-class inclusion through new channels of communication and interaction. Solutions will be viable for traditional classroom environments as well as for lab sessions, study groups, and project meetings. And because our work will parallel that of other educational technology, we will follow universal design guidelines so that the technology used by deaf and hard of hearing students is compatible and seamlessly coexists with educational technology designed for a general, mainstream audience. By utilizing networked resources and flexible design that empowers students, we hope to create a more inclusive, easily accessible classroom environment.

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