A Teaching Model for Teaching Deaf/Hard of-hearing and Hearing Students with Course Accessibility and Real World Product Design

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Engineering University Classrooms that Incorporate Accessibility and Real-World Product Design

Teaching engineering for deaf, hard-of hearing (D/HoH) students presents several challenges as well as many rewards. For D/HoH students to be mainstreamed into a regular engineering program presents a series of barriers that they need to overcome. D/HoH student's language characteristics are more similar to foreign students because written and spoken English is their second language and they often function similarly with respect to English discourse, semantics, and sentence interpretation [(1) (2).]

Engineering course material generally does not consider any type of learning accessibility for D/HoH students. While the university provides resources (such as e.g. sign language interpreters, note takers, real time captioning and specialized mentoring faculty), the instructors in the classrooms sometimes are not suited for the learning environment of a D/HoH student. As an example, during a regular lecture, D/HoH students have to be paying attention to the presentation slides while taking notes on the content written on the whiteboard, looking for instructor's expressions while at the same time looking at and understanding the sign language interpreter's messages. Even more challenging for the D/HoH students is that sign language is a visual/idea oriented language and interpreters do not provide a word-by-word translation of the instructor's spoken words.

Given the above challenges, the following proposed modifications are recommended for courses, classroom environments, and the overall D/HoH learning experience in engineering programs. We have several success stories by guiding students through this new process with the access service support and departments involved. In addition, some D/HoH students had the opportunity to participate in cooperative education learning at the National Technical Institute for the Deaf (NTID) Center on Access Technology (CAT) Innovation Laboratory, where students are working on real world design of engineering products supervised by the faculty from Engineering, Engineering Technology (ET) and NTID departments.

The experience and proposed modifications start at the freshman-level courses through the advanced senior design projects. The objectives are to integrate team building skills, multidisciplinary collaboration, and good engineering practices. Students have been so engaged developing products and they have presented their work to small and large audiences such as the university innovation festival that is a family and industry oriented event.

Based on the author's experiences in teaching, researching, supervising and collaborating with D/HoH students, some success stories were selected to build the framework to present modifications to be incorporated in courses, university infrastructure, personal mentorship and opportunities that help D/HoH succeed and build the skills for a fruitful career in different engineering disciplines. Through the enhancement for the D/HoH students, all other hearing students will also benefit from it.

Introduction

Traditional approaches of teaching university-level engineering courses present challenges to students who rely primarily on visual learning such as D/HoH students. Currently there are over 31,000 D/HoH students enrolled in college and this enrollment number is up 15,000 over the past 10 years [3]. While the current trend of real-world careers and product design demand highly qualified engineers with various skills, including visual skills, most engineering classrooms are not designed to utilize students' visual skills and are not fully accessible by D/HoH students. When classrooms maximize the benefits of visual learning, the common barriers of traditional pedagogy — i.e., using spoken English as the primary mode of communication with English as Second Language (ESL) students — are partially ameliorated.

The purpose of this paper is to sensitize hearing engineering faculty to the cognitive and sequential processing needs of D/HoH students who primarily rely on visual input for learning. In contrast to hearing students who may be able to look at a graph or written equations and simultaneously process what the professor is verbally clarifying with respect to the visuals, D/HoH students do not have the luxury of simultaneous parallel processing. In fact, even the hearing students do not necessarily do well with multi-media presentations due to cognitive overload [4]. In addition to the instructor presentation issue, engineering students also have to participate in projects and co-ops with other hearing people. Thus, this paper focuses on both classroom-based and project-based strategies for the instructors and co-op strategies for the students.

Even when accommodations are provided for D/HoH students, such as sign language interpreters, note takers, real-time captioning, and specialized mentoring faculty, it is vital for the instructor to understand the needs and benefits of using visual learning strategies to help D/HoH students. For example, during a lecture, D/HoH students have to pay attention to the sign language interpreter to understand what the instructor is speaking, but they also need to divert their vision to the notes on the whiteboard and/or the presentation slides—forcing them to miss what the instructor is saying. This results in what Mayer, Heiser and Lonn [5] have identified as cognitive constraints on multimedia learning. Furthermore, such multiple presentations of information force students into a multitasking mode that may hinder their ability to focus [6]. The ideal solution is to have the instructor make adjustments to utilize more visual strategies of teaching in a sequential logical manner that allows D/HoH students to focus and process relevant content without missing out on parallel messages that are being presented verbally by the instructor.

The National Technical Institute for the Deaf (NTID) at Rochester Institute of Technology (RIT) has developed an innovative model for improving the classroom environment and overall experience for visual learners in STEM fields, particularly with respect to engineering courses. Marschark, Sapere, Convertino, and Pelz [7] have noted a number of communication access strategies for STEM education. We have several success stories guiding students through this new process in addition with the access service support and departments involved. Also, some D/HoH students had the opportunity to participate in cooperative education learning at the NTID Center on Access Technology (CAT) Innovation Laboratory, where students work on real-world

design of engineering products supervised by the faculty from Engineering, Engineering Technology (ET) and NTID departments.

Background

Rochester Institute of Technology is a privately endowed, coeducational university with nine colleges emphasizing career education and experiential learning. The campus occupies 1,300 acres in suburban Rochester, NY. The RIT student body consists of approximately 15,000 undergraduate and 2,900 graduate students. RIT is an internationally recognized leader in preparing deaf and hard-of-hearing students through the National Technical Institute for the Deaf (NTID) for successful careers in professional and technical fields. The university provides unparalleled access and support services for the more than 1,300 D/HoH students who live, study, and work with hearing students on the RIT campus. Approximately 573 D/HoH students are enrolled in science, technology, engineering or mathematics (STEM) programs. These students, particularly those in the engineering fields, engage in the projects of the NTID Center on Access Technology Innovation Lab.

Classroom Based Strategy

A significant challenge is maintaining direct interaction between an instructor and D/HoH students. There are two most common communication preferences those D/HoH students use in the classroom. Usually the hard-of-hearing students with very mild hearing loss would prefer to use listening devices and speechreading skill. Majority of them have cochlea implants (CI) or wear hearing aid devices. Some of them may use FM loop device in addition that only picks up the instructor's voice and discriminate other environmental sounds. This method is exhaustive because it requires students to put effort to focus on instructor at all the time to maximize in gathering the information as much as possible. By doing this, the students may not fully grasp the concept or content that instructor tried to accomplish. In contrast, typical deaf students would use access services such as sign language interpreters and C-print as a primary means of in-class communication. The down side effect is that the translations from the sign language interpreters and C-print operators are generally paraphrased and may not be entirely accurate and representative of the complete lecture. According to Marschark, Sapere, Convertino, and Pelz [7], D/HoH students in the classroom only receive about 30% of the information through interpreters.

With either styles of communication, students may lose connection with their classroom instructor when he moves away from direct interaction with students toward a whiteboard to write equations, draw diagrams, charts or pictures, or to access a computer or screen projector in order to present PowerPoint slides, videos, or other media. These disconnects, however brief, disrupt the flow of communication between the instructor and students, and as a result students struggle to stay engaged. It is important for instructors to establish direct eye contact with students, and continuously survey the room for cues, such as head nods or facial expressions, in an effort to accurately gauge whether or not students are following the discussion. These subtle cues provide the instructor with the assurance to continue on with the discussion or to stop, reiterate and reinforce subject material. Occasionally, a student will ask the instructor to repeat but not very often because it could interrupt the teaching flow of the classroom. It is understandable that the instructor cannot focus only on students with special needs all the time

because the instructor's main responsibility is ensuring that the learning of the majority of the students is productive and effective.

For D/HoH students, accessibility is a necessity and required. A sign language interpreter or C-print operator is usually provided in the classroom. The role of the sign language interpreter or C-print operator is to translate the instructor's spoken words into visual language. These are additional variables that D/HoH students need to focus on beside the content information being presented via technology and the instructor.

As a result, typical technologies in the classroom such as PowerPoint presentation, SMART/White boards, instructor, interpreter and C-print often disrupt D/HoH students' learning due to dividing their visual attention (too many focus points and steps) between the information sources which are often spatially distributed around the classroom. Research conducted by Kushalnagar, Kushalnagar, and Pelz [8] used eye tracker technology to monitor D/HoH students' attention to different focus points in the classroom, and their findings indicated that students spent a lot of time moving their eyes to different focus points while missing some of the information. They were not able to remain fully engaged with an instructor through the lecture.

Effective Communication Tips for the Deaf and Hard-of-Hearing Students

With a basic understanding of what visual communication is involved, the instructor can design a class lecture that minimizes the focus points, such as the following:

- Create a classroom environment where students are fully engaged with the instructor by having close proximity between the instructor, support service and different sources of information.
    - Because of hearing loss, the students tend to use visual processing much more than hearing students. The goal is to reduce the effort from looking one place to another. Some instructor like to walk around in the classroom or move back and forth in the front of the whiteboard and creating visual challenges for D/HoH students
    - Below are two different examples that may be beneficial to the students;
        - For hard-of-hearing students who use CI or hearing aids with or without FM devices can sit in the front row and the instructor can establish direct eye contact with students, and continuously survey the student for cues, such as head nods or facial expressions, in an effort to accurately gauge whether or not students are following the lecture. This will allow the students to use their listening or speech-reading skills as much as possible. Also, it is important that the instructor stays close to the Powerpoint presentation while giving a lecture so that the students can minimize focus switching as possible between the speech-reading and the presentation.
        - For those students who prefer to use sign language interpreters, they are encouraged to sit in the front row and the sign language interpreter should stand as close as possible to the instructor. The instructor may not feel very comfortable, but it will be helpful for the student to follow the interpreter and instructor. When the instructor uses the whiteboard or

PowerPoint presentation, it is important that the instructor, interpreter and the whiteboard/Powerpoint presentation be as close as possible to each other. This approach minimizes the interactive distance or space between the instructor, whiteboard/presentation and interpreter. A C-print operator generally sits among the students and they have a laptop computer where the real time text is displayed.

- Minimize the number of tools and media that are currently available to aid in the teaching.
    - The use of technology in the classroom in the last 40 years has forever changed the traditional teaching and learning environment. The addition of digital learning tools, such as computers, overhead projectors, SMART boards, and handheld devices, have positively impacted the teaching and learning process by increasing motivation and self-esteem, improving technical skills, and fostering communication and collaboration among both teachers and students. Further, technology has provided an increase in educational opportunities for all people through methods such as virtual or online learning and remote tutoring. In short, technology provides endless possibilities to improve teaching and learning.

    - The adaptation of new technology and processes always comes with inherent challenges. The amount of tools and media that are currently available to aid in the teaching and learning process are vast and will continue to grow at a steady, if not, rapid pace. Teachers are utilizing these tools daily, often combining multiple methods simultaneously (e.g., presenting PowerPoint slides while writing on the whiteboard) in an effort to be as thorough as possible and reach a wider range of learning styles. The utilization of multiple learning tools presented in concert means that the students are no longer focused exclusively on the teacher. Their visual attention is divided between all of the different sources of information. However, hearing students are still engaged with teachers through spoken language. This is problematic for deaf and hard-of-hearing students for numerous reasons as previously noted.

    - Different sources of information being presented are displayed on multiple devices (e.g., SMART board to show a video, PowerPoint slides projected on a screen, etc.), and these devices are usually not in close proximity to each other or the instructor, who should remain the primary focus. As such, students have to constantly scan the classroom in order to take in all of the resources that are available to aid in their learning experience. Students often become distracted, and may or may not be looking at the right source of information at the right time. Further, the constant scanning results in eye fatigue. Although the degree of eye fatigue depends on the length of discussion and the type and quality of information, it is widely realized that an increase in eye fatigue results in a decrease in focus and learning comprehension.

- Review the “Teaching Tools: Top Ten Teaching Tips” from Teach2Connect website supported by RIT/NTID. The purpose is to provide instructors with classroom teaching

strategies that can create an environment where D/HoH students are fully engaged with the instructor and hearing students.
This website is http://www.rit.edu/ntid/teach2connect/. It has valuable resources to assist instructors who may have not worked with D/HoH students before.

Laboratory Based Strategy

For the lab, the tips for effective communication is similar to the classroom except that the students may have to deal with additional devices such as computers, instruments and/or developmental / electronics kits. The challenge is that not only must students have to focus on the instructor and interpreter; they have to look at lab instructions and devices as well. For example, when the instructor goes through step-by-step in setting up the instrument for electronic measurements, the D/HoH student needs to setup the instrument before he/she can re-establish focus on the instructor. For a hearing student, he/she can set up the instrument while listening to the instructor. It is important to create time to allow students to setup the instrument, to see the information on the devices or to absorb presented visual aid/information before the student move to the next step. The D/HoH students will appreciate and be motivated if the instructor makes the time.

Project Based Strategy

In typical project activities, engineering students have to participate in project assignments with other hearing students. It is required for any engineering students to develop people and communication skills through group projects. In a group dynamic, it is very difficult for D/HoH to follow the conversation as well as for an interpreter to keep up with different students' talking. One of the tips is to have an interpreter behind the students when they are talking so that the D/HoH students can see the student and interpreter together. It is challenging for D/HoH to be fully immersed in a group discussion with hearing students. It is also an opportunity for hearing students to learn in dealing with D/HoH students. Not every interpreter is highly qualified in terms of the various engineering disciplines and the vocabulary or nomenclature specific to each discipline. The students know that they need to develop the communication and hand-on skills before they work in the industry.

Co-op Based Strategy

In an ideal situation, there should be some kind of an engineering development center on the university campus where D/HoH students can have their first co-op experience. Based on experiences at NTID, D/HoH students were better prepared after their first co-op experience. A number of D/HoH students who took their first co-op with NTID Center on Access Technology, have accepted a co-op or permanent positions with companies such as CISCO, Department of Defense, Google, and NASA.

The NTID Center on Access Technology Innovation Laboratory ("CAT Lab"), a first-of-its-kind initiative, provides a place for students to become involved in the innovation process by participating in the creation of specialized access technologies. The expectation is that all participating students would be fully involved in the process of innovation, not just participating

as research “subjects” or assistants. They would have an active role in all aspects of a real-world product design project.

The lab partners within the university and with external organizations to offer students a unique opportunity to specify, design and build innovative access solutions, specifically for D/HoH persons; using practical development and business models.

The CAT Innovation Lab brings together faculty and D/HoH students to collaborate on multidisciplinary projects related to developing and adapting access and instructional technologies, health care technologies and services.

One of the key advantages is to allow D/HoH students to take their first or second co-op at the CAT Innovation Lab. Because the projects are managed by a director who has over 30 years’ experience in the industry and has a comprehensive awareness of the issues associated with D/HoH students. The director of the lab is a tenure-track, faculty member at RIT and has responsibilities for direct instruction and direction of the lab.

The following is a general model that is applied to all projects within the CAT Lab. This model is used to highlight the features of three exemplary CAT projects, in various stages of development.

1. Model of a Project

a. Accessibility needs / problems
b. Feasibility for technical solutions
c. Business needs (will it benefits others?)
d. Engineering skills requirements (students and faculty members)
e. Communication requirements
f. Resources (skills, availability, lab, equipment, etc.)
g. Funding / grants
h. Project management
i. IP / technology transfer and marketing opportunities
j. Prototype development process
k. Actual solution / results / publications

Within the overall structure of the CAT Innovation Lab, a formative evaluation process is utilized to measure not only the technical success of efforts, but also the educational outcomes from both an individual student perspective and a curricular level.

Additional traditional marketing strategies, such as focus groups on usability, product effectiveness and cost-benefit analysis are used. Some solutions are immediately used in the targeted educational or working environment, normally as an “add-on” to provide immediate solutions and hopefully the design will eventually integrated into the overall design of future products.

Success Stories

The following three D/HoH success stories were selected based on six criteria:

1) improved communication skills
2) more involvement with hearing students
3) better performance with academic school work and related activities
4) ability to solve engineering problems
5) opportunity to innovate and develop prototypes
6) preparation completed for co-op work experience in industry

Project: See-through Life-size Interactive Monitor System (SLIM)

a. Accessibility Need: Improve engagement in the classroom for the D/HoH students.

b. Technical Solution: SLIM - The See-through, Life-sized Interactive Monitor creates engagement of teaching by allowing teachers to face their D/HoH students while writing on the see-through board. It consists of two large monitors placed back-to-back.

c. Resources:

i. Educational Environment: The project began in 2010 with 6 co-op students (3 deaf and 3 hearing students) being hired. Their majors were in computer science, software engineering and mechanical engineering.

ii. Business Model: Internal operation began within the CAT Lab and now is in the process of establishing collaboration with outside companies.
The first stages of the project started with internal seed funds, and with successful progress in the development cycle, the efforts have expanded with several grants submitted and some external funding received.

iii. IP Resources: Received a provincial patent

iv. Entrepreneurial Environment at RIT: Not mature enough yet to begin the business stage of the process

d. Development Model: The project started as a proof of concept and it has evolved into a working prototype. The project is in the process of setting up collaborations with potential partner companies.

e. Result: The students worked together effectively and delivered a working prototype.

Project: Smart Cane

a. Accessibility Need: A better navigation system for the deaf-blind persons

b. Technical Solution: A smart cane

This project will design, develop, and test a “Smart Cane” that will aid a blind person in navigating an environment via real-time tactile and directional force feedback and guidance.

The prototype cane will be based on a standard long white cane shaft that is familiar to users. The user handle of the cane has a built-in sensitive tactile pad, and a detection system is mounted toward its tip. The sensitive tactile pad includes an integrated directional force feedback rumble unit that causes the tactile pad of the cane to vibrate in selected obstacle situations. The vibrations inform the user where and how far an obstacle or object is in real time.

c. Resources:
   i. Educational Environment: 3 co-op and part time engineering students (2 deaf and 2 hearings) were hired for this project.
   ii. Business Model: Started with internal seed funds and the project is in the process of submitting new grant proposals.
   iii. IP Resources: RIT has two patents granted from IBM for this project
   iv. Entrepreneurial Environment at RIT: Not mature enough yet to begin the business stage of the process.

d. Development Model: The project started as a proof of concept and evolved into a working prototype. The project is in the process of setting up collaboration with a company.

e. Results: It was a challenge to get all four students to work together. One of the biggest problems was related to communication and at the end of the project they were able to develop their way of communicating and working together.

Project: Lab Instrumentation Sound Detection (LISD)

a. Accessibility Need: This project focuses on assisting D/HoH scientists/technologists and healthcare workers using specialized lab instruments. There are many lab instruments that do not meet the accessibility needs for D/HoH people. Challenges including filtering and detecting the sounds, as well as communicating with and notifying the scientists/technologists.

b. Technical Solution: The lab instrument sound detection was developed to detect a high-pitch sound and notify a user via smartphone, email, or text when the instrument is finished. The immediate solution is designing and developing an add-on notification device used for detecting the sound indicators. It is expected that the notification technology that is used in the add-on can be engineered to be part of the overall user interface of future products, so add-on technology will not be needed.

c. Resources:
   i. Educational Environment: 3 – deaf co-op students (2 – software engineers and 1 – mechanical engineer)
   ii. Business Model: Started in the CAT Innovation lab with seed fund and the project is in the process of writing a new grant proposal.
   iii. IP Resources: Not yet utilized
   iv. Entrepreneurial Environment at RIT: Not mature enough yet to begin the business stage of the process.

d. Development Model: The project started as a proof of concept and it evolved into a working prototype.

e. Results: The co-op experience prepared the students to academically excel with their course works.

Summary and Recommendations

Access Services

The function of all access services is to facilitate access to communication between the deaf, deaf-blind, hard-of hearing and hearing (instructor and student) individuals who work, learn and interact in the classrooms, laboratories and community. Usually a sign language interpreter or C-print operator is provided in the classroom. The role of the sign language interpreter or C-print operator is to translate from the instructor's spoken words into visual language. These are additional variables that D/HoH students need to focus on beside the content information being presented via technology and the instructor. Some instructors assume that by having access services, the D/HoH students are on par with the hearing students in learning. This is a common myth and it is not true for almost all cases.

The instructor may not know if there is a D/HoH student taking his course. It is always appropriate to ask the students in the classroom if they need any specific accommodations. The instructor is not responsible for students' accommodations, but he needs to refer the students to University's accessibility service office.

Classroom Settings

The goal is to create a classroom environment where students are fully engaged to the instructor through close proximity between the instructor, access service and different sources of information. The challenge is to minimize the interactive distance between students, instructor and support service. In a typical classroom setting, an instructor stands next to the projector screen and the sign language interpreter sits near to the D/HoH student. The D/HoH student will have to put extra effort in focusing on the sign language interpreter, looking at the instructor and taking note at the same time. It is an ideal if all three (instructor, interpreter and screen) are put together as close as possible.

If the interpreters can have the course materials in advance, they can prepare themselves before the class. They understand that course materials are not public information and should not be distributed. Usually interpreters want to increase their sign language skill in engineering because there are very few D/HoH in engineering fields as compared with other non-engineering fields. There are no clear standard signs for different technical / engineering terms. In the last 40 years since NTID was established, some level of sign language for technical terms have been developed but a lot of more work need to be done. And because technologies have changes rapidly in the last decade, it is hard to keep up in developing new technical signs.

It is typical for instructors to tryout different tools and media that are currently available as teaching aids. It is suggested that the number of tools and media be controlled which will maximize the student's visual attention.

Laboratory Settings

The difference between a typical engineering lab and a classroom is the addition of a computer, instrument, or a development kit in front of the student. The instructor needs to ensure that the D/HoH student has a chance to see the information or do the setup before the instructor can proceed with the lecture.

Group Discussions

The goal for D/HoH is to be fully immersed in group discussion and activity with hearing students. A small group of 3 or 4 hearings will be ideal for the D/HoH student to manage with an interpreter. Also, worth to mention that especially in the engineering fields, there may not be many interpreters that are highly qualified. It is beneficial for the instructor and D/HoH students to work with the interpreter to increase the effectiveness of translations.

The D/HoH students need to be reminded that it is also an opportunity for them to learn to deal with hearing people. The instructor needs to motivate them to develop the crucial interactive skills before they work with engineers in the workforce. Many of students may not realize that to be a successful engineer, it is required for them to become an excellent communicator.

Course Materials

For many D/HoH students, their language level may not be what is expected for college standards due to their physical lack of access to spoken language. There is no feedback for a person to hear and correct and improve their language. It is helpful if visual aids are included in the course materials. Selecting a text that has visual instructions and pictures will be beneficial. Instructions similar to building Legos can be used for following the lab instructions. Because of widespread use of smartphone devices, the instructions can be easily developed by capturing pictures and drawings of the lab setup or system configuration.

Based on the authors' experiences in teaching, researching, supervising and collaborating with D/HoH and hearing students — as well as modifying courses, university infrastructure, personal mentorship — focusing on visual strategies of learning, this paper describes ideas of how to address some of the accessibility needs of D/HoH students. However, given the above list of recommendations and tips for effective learning accessibility of D/HoH students, it is not exclusive. The framework is in the right direction of reaching toward to positive learning experiences of the D/HoH students in STEM field.

The experience and proposed modifications are recommended to start at the freshman-level courses to the advanced senior design projects. The objectives should include integrating D/HoH students in effective learning environments, team-building skills, multidisciplinary collaboration, and proven engineering practices. Students engage with developing marketable products and

they will have opportunities to present their work experiences to their peers, instructors and potential employers. The reward is for the D/HoH engineers to be prepared and ready for work employment.

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