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Physics Education Through S.T.E.M. Outreach

Physics 492R Capstone Project Report

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Abstract: Science Technology Engineering and Math education is increasingly important in our world as we continue to build a highly technical global society. I have sought to prepare myself to be an effective physics teacher and STEM educator with every opportunity I have been given throughout my education. The redevelopment of both a local BYU acoustics outreach program as well as a national outreach program for the Acoustical Society of America is what I have accomplished. My work has given me a better understanding of the use of pedagogy in a variety of educational setting including teaching sound to the deaf and hard of hearing as well as the use of demonstrations in education. My work has focused on understanding Utah Core Curriculum and implementing those parts that revolve around acoustics specifically for middle, and high school aged students as well as the general public. This work has prepared me to be an effective educator as I go forth to serve in public education as a high school physics teacher.

I started my college career as a Physics Teaching major and later changed to Applied Physics with the desire to teach high school physics and help children learn how to discover their universe through scientific reasoning. My degree required taking a class looking into research and career opportunities in physics early on in my education. This requirement was confusing, since I knew what I wanted to do. Dr. Stokes gave me some wise council on the class's importance to me. He told me that students will always ask, "Why?" and "What can I ever do with physics". I realized I needed to learn how to answer these questions and help students discover how they could personally utilize the knowledge they would seek to gain in my classes if they cared enough. Answering these questions soon became one of my favorite games with students.

One of the main outcomes for this class was to get students involved in research early in their college careers. Many of my close friends in the program became involved in really interesting and important research that would jumpstart their futures and expertise in various fields of physics. I wanted an opportunity that would also jumpstart my future and expertise but didn't feel research was going to do it for me as a soon to be public classroom instructor. Where was I going to gain the practice and hands-on learning in how to be an effective physics teacher or really any classroom/teaching experience at all in my education? As scheduled, I wasn't to gain significant experience until I did my student teaching toward the end of my college career. This left me unaware of how well I would truly enjoy the classroom until then.

From visiting research groups, I became aware of the Acoustics Research Group (ARG) outreach program. I immediately volunteered to help out with the first opportunity giving big demo shows to Japanese middle/high school students who were visiting BYU. I was given a few demos to present and it was a blast as I quickly became more and more involved in the program.

I was asked to help improve this outreach program, which quickly became a very fun and productive capstone project for myself under the direction of Dr. Gee and Dr. Neilsen who agreed with the plan. I became the Acoustics Outreach Coordinator. My tasks were to research Utah State Core Curriculum involving acoustics and the general phenomena of waves and correlate the program with it, organize all outreach resources, and ultimately make the program able to be carried on with ease after I graduated and went forth to serve from BYU.

The State of Utah is following the nation in the movement toward a common core. This is currently only focused on language arts and mathematics but may have future cause to adapt with the Next Generation Science Core. The initial focus was to know K-12 Utah State science core curriculum. More specifically, I was looking for curriculum related directly, or indirectly to acoustics, or the physical study of wave phenomena. I found that students were first introduced to acoustics in the 6th grade, then in 8th grade and not again unless students took physics in high school. Even in high school, physics classes typically spend only a couple days to a week studying acoustics.

This was of great concern since acoustics is one of the fundamental ways to model the interactions we observe in the universe. From electricity and magnetism to optics and energy transfer, everything can be modeled to act as a wave. This, coupled with a common misunderstanding that the term "acoustics" only dealt with guitars led me to believe there was much to be done to make the general public more aware and to take the education of acoustics more seriously through outreach efforts.

The Utah science core states, “The main intent of science instruction in Utah is that students will value and use science as a process of obtaining knowledge based upon observable evidence.” To do this, the 6th and 8th grade science core emphasizes hands-on inquiry as the fundamental scientific process that students should learn to utilize in their science education. They are also encouraged to be active learners in the scientific process and sustain their curiosity through science inquiry.

Inquiry was the pedagogical focus for the state, and also seemed to be the best pedagogical approach for an outreach program to be developed on. This idea was also exactly what my advisors, Dr. Kent Gee and Dr. Traci Neilsen, thought was best for the Acoustical Society of America’s national outreach program which they were currently highly involved in discussing how to redevelop. This task they soon passed on to me because of the work they saw me doing with BYU’s outreach program.

Over the past two years I have been redeveloping the outreach program for the Acoustical Society of America (ASA) specifically catered to middle/high school students and girls scout troops. Structure, management, pedagogy used, and presentation of the programs were all considered. We felt that current physics education research showed that a hands-on approach at inquiry learning was the best method for an outreach event. The structure of the program was refined to specific stations each focused on a specific physical system and general learning outcomes brought about through inquiry learning. To aid in this, equipment and demonstrations used were organized for each station along with volunteer instructor guides. Station posters for added professionalism and presentation were designed and created a strong aid to trigger participants thought processes about each station. All these developments and efforts made culminated in a national presentation at ASA, a regional presentation at AAPT, a local presentation at the SRC, and a published paper detailing all this work.

My efforts sought to break down each demonstration used to explore ways to improve them individually and collectively as a whole outreach program to teach the physical principles of acoustics more effectively. One of the stations developed was based on electronic music. This station sparked an interest in the use of free audio software in acoustics education and resulted in another national ASA presentation on the use of Audacity to teach basic physical principles of acoustics. This gave me an opportunity to learn new software and explore how it could be used as a teaching aid. We found that Audacity could be used to demonstrate and teach about sound cancellation, additive synthesis, reverberation, attack and decay of sound especially in musical instruments, filters, and much more.

Many of the ASA outreach stations focus in on the physics behind musical instruments, many of which are not as well understood as we would imagine. Correlating research that had already been done at BYU as well as research topics that were currently being done in BYU’s Acoustics Research Group, we questioned exactly how to explain the phenomena of one demonstration involving a hammered dulcimer, one of the precursors to today’s piano. This led to another presentation given at ASA which questioned the hammer-string interaction and exactly how that played a role in the sound/waves created. This was especially interesting due to the historical use of the hammered dulcimer as one of the instruments that aided Marin Mersenne in the development of the mathematical relationship between frequency, mass, tension, and length in a string fixed at both ends. This research involved high-speed video analysis of the hammer-string interaction to understand how exactly the hammer effected the strings and vice versa.

Overall my activities with the ASA gave me real world professional experience with education. I had the opportunity to develop demonstrations, learn how to utilize effective pedagogy as well as curriculum development, and practice instruction skills to both students and other instructors. This is exactly the experience I sought to gain in preparation for my career as a high school physics teacher. My activities in developing the ASA stations are described in an article published in Proceedings of Meeting on Acoustics, which is attached as Appendix A.

My second opportunity for publishing an education-related article came with my involvement in creating an acoustics outreach program for the deaf and hard of hearing. In conjunction with BYU research in AR (artificial reality) glasses for deaf education in planetarium shows, the BYU ASA student chapter was asked to teach students from a school for the deaf and hard of hearing about sound. This interesting challenge led to a pilot study into how to adapt acoustics pedagogy for the deaf and hard of hearing. We focused on the used of multisensory pedagogy which allows for multiple learning styles as well as more fully engaging student minds in the learning process. Typically the two strongest and most utilized senses in education are visual and auditory. We quickly realized that the best way to use multisensory education was to adapt this pedagogy to the use of visual and kinesthetic learning, in which students would learn about sound by seeing it and feeling it. A paper describing these efforts in full has been submitted for publication with *The Physics Teacher* and is attached as Appendix B.

An example of a demonstration used was a laser shining on mirrors that were mounted to speakers in order to show how sound was made up of unique vibrations. These vibrations were evident in circular patterns reflected on the wall from the laser reflecting off of the two vibrating mirrors. This demonstration was also capable of demonstrating that vibrations can be combined to create more complex patterns and sounds by driving two individual pure tones through the two different drivers or by playing complex sounds, such as music, through them. This demonstration was specifically made for this pilot study and includes detailed instructions on how it was built, how to fix it, use it, and teach with it.

This demonstration is a great example of what I was striving to seek all around for my capstone project. I evaluated what was being done and sought new ways to improve teaching and learning. In this case, there was a need that inspired me to find a new demonstration that could be built to better teach the specific audience that I had and with the specific pedagogical approach we felt best. The focus was in learning how to apply various forms of pedagogy and to discover my teaching style that I may better prepare to be an effective high school physics teacher all throughout my education. I learned how to develop curriculum, lesson plans and methods of instruction based on core curriculum. I also learned how to better organize and instruct individuals how to teach effectively as well as instruct and manage students.

Without these experiences that I sought out and which opened many new doors, I would not have had much experience with teaching beyond one semester of student teaching. The work that I have done with ASA and BYU has brought about a stronger excitement for education, especially through STEM outreach, which will ultimately inspire the next generation of STEM professionals. It was rewarding to see how many of the ASA members who volunteered to help in these events may have come to the ASA conferences ready to share, at a highly intellectual level, their research and expertise and collaborate with their colleagues, but left with the excitement that comes from being able to also share their research and expertise with young individuals and see their excitement in STEM fields grow. I feel that if science and education in general are fun, then learning can really happen because students are engaged, excited, and taking ownership of their education. Each participant who has commented on both ASA's and BYU's acoustics outreach programs have made mention on how fun they were and how each student took ownership of their education at these events. Some comments given to me directly have given me confidence that many people agree that I am prepared to be an effective and engaging educator. This work has strengthened my passion for STEM education as well as my experience and I now feel prepared to go forth as serve the students of Copper Hills High School as their new physics teacher this coming school year.

Acknowledgments

I would like to acknowledge the support of my advisors Dr. Traci Neilsen and Dr. Kent Gee. Without their guidance throughout my education I wouldn't have had so many opportunities to gain these important experiences. I also want to recognize the support of the Acoustical Society of America and BYU's Department of Physics and Astronomy for support in all that has taken place in my capstone project. I also appreciate the help of Dr. Jeannette Lawler, Jenny Whiting, Mark Berardi, Katherine Fortney, Menley Stewart, Ben Christensen, Darren Torrie, and the rest of BYU's Acoustics Research Group outreach team members who have played an integral role in assisting me in bringing forth all of these accomplishments.

APPENDIX A: PROCEEDINGS OF MEETINGS ON ACOUSTICS, 2014

Development of educational stations for Acoustical Society of America outreach

INTRODUCTION

Science outreach programs can play a valuable role in shaping attitudes and future educational goals when they capture and build upon the interest of participants. A traditional difficulty, however, has been the development of outreach programs that can efficiently train[1] facilitators to interact meaningfully with participants and also reach a sufficient diverse audience[2] in order to promote learning. The Acoustical Society of America (ASA) has a history of conducting outreach workshops for secondary education in conjunction with its semiannual conferences. These sessions began in 1987 thanks to the efforts of Uwe Hansen and others in the Education in Acoustics committee. In 2008, Marcia Isakson and Tracianne Neilsen started a similar outreach session for the Girl Scouts of America as an initiative for the Women in Acoustics committee. Many ASA members have volunteered their time to make these events successful. The goals of these outreach activities are to provide a public service, generate enthusiasm, build awareness and supplement learning. To build upon the foundations built with these past programs, the structure of these outreach workshops has recently undergone changes to address some concerns and advance the goals of the outreach sessions through stronger pedagogical techniques and increased efficiency.

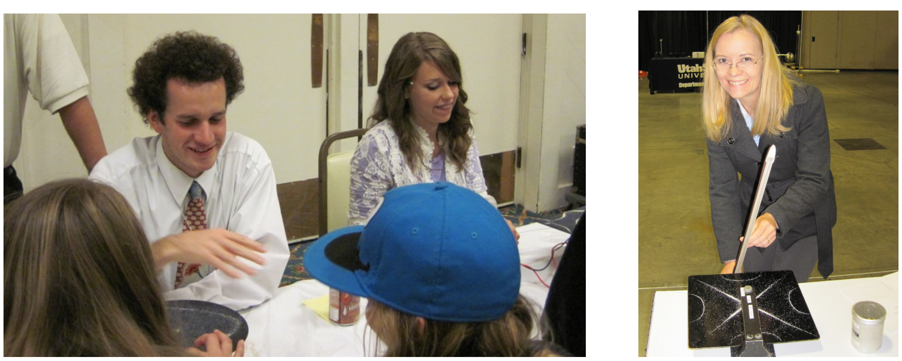

Figure 1. Left: ASA student member volunteers and Girl Scouts at 167th meeting of ASA in San Diego, CA. Right: Dr. Traci Neilsen demonstrating the Chaldni plate.

The goal to develop a unified structure of the ASA outreach workshops and to provide the opportunity for participants to leave with a better understanding and appreciation for a Science, Technology, Engineering, and Mathematics (STEM)-related field, has been advanced on several fronts. First, a brief introductory presentation for the sessions has been made to generate excitement, give examples of what can be done in the field of acoustics, and get the students engaged with the material so that they could gain the most out of the experience. This supports the pedagogical argument[3] that in order to shift to learner-centered teaching, the students must understand their role and be empowered to accomplish it.

Second, the demonstrations have been grouped into five-minute, hands-on stations each pertaining to a different physical system. A similar format[4] has previously proven to be highly effective in increasing the efficacy of outreach efforts in other outreach programs. Each station has a specific learning outcome based on a real-world acoustical application. How we hear and how string instruments work are examples of the 13 main physical systems explored in these stations. The hands-on stations become an opportunity for a learner-centered environment when an inquiry-based[5] format is used. With this intended standard, the students will be guided to personally engage with the material and gain an appreciation of how the science of sound influences their daily experiences. In addition, creating a consistent structure for the hands-on portion of the session is key in increasing efficiency of the management and production of the outreach sessions.

Figure 2. ASA member assisting local students at 166th meeting of ASA.

Third, to increase the ease with which volunteers can assist with the stations, one-page summaries and reference posters have been developed that outline the basic principles to be explored at each station. A concern that had been raised was that many of the volunteers are hesitant to help because of a lack of understanding of what is expected of them. They often do not feel prepared to give an impromptu lecture. However, as traditional lecture methods of teaching have been shown to be one of the least effective[6] methods in learning physical principles, the prepared station outlines assist volunteers to more easily understand their expectations. The written outlines also provide volunteers with a guide on how to troubleshoot the equipment used in the hands-on demonstrations and to understand clearly their roles in guiding the children through inquiry based learning.

Figure 3. ASA member and local student at 166th meeting of ASA exploring body resonances of string instruments.

The preliminary results of these efforts are presented in this paper. A further description of the introductory video and the hands-on stations are given. Examples are included of the station outlines provided for volunteers. The first implementation of the revised outreach workshops took place at the 166th meeting of ASA in San Francisco in December 2013. The initial reactions of the students and members as well as recommendations for future improvements are discussed.

RESULTS

Our plan was to increase the efficacy of the ASA outreach activities through pedagogy, the stations used, and more efficiently utilizing volunteers. The modifications have not only provided more structure and order to the program, but they have increase the value of the outreach efforts. Applying concepts of active learning from physics education research, we have created an introductory presentation, provided volunteers guidance on how to interact with students and given volunteers an inquiry-based structure all built on active learning principles in science education.

The introductory presentation involves both a short thought provoking video and a few slides explaining the expectation for the students. The five and a half minute video "Amazing Acoustics" (https://www.youtube.com/watch?v=IGfAL8KgHMc) is designed to get participants thinking about what the science of sound is and connecting it with their daily lives. The short presentation that follows the video explains how the students will proceed through the session exploring acoustics with the help of professionals at the different stations. This helps them understand their role in the learning process and establish order during the sessions.

It was important to clearly explain to the volunteers what they would be expected to do. We made clear that we wanted them assisting students through question-driven exploration of basic acoustics principles, such as how string instruments create sound, and that they would receive materials to prepare them properly. We also held a short training before the students arrived. This helped volunteers understand the format and give them time to familiarize themselves with the materials provided for them at each of the different stations and answer any further questions they had. Volunteers were enthusiastic and very helpful once they understood the purpose of the outreach sessions and gained an idea of what it would entail.

One of the key materials provided to volunteers was a one-page laminated summary for the stations. This outline and the brief training gave the volunteers all the tools they needed to help guide participants through the learning process. The outlines contain a picture of the station setup, a list of equipment that was provided, a question bank and a reminder of the volunteers' basic purpose. The list of questions are effective examples for inviting participants to think more critically about sound and therefore learn the principles governing the physical systems. These questions are not meant to be a complete list, but rather to help volunteers understand the types of questions that could be useful in gauging what participants already know about the physical system they were exploring, and then to help them think more deeply than they previously have about the system. A couple examples are given in Figure 7 and 8 at the end of the article. Each summary has a reminder that simply says, "*Engage audience for approximately 5 minutes by exploring the topic together by asking questions and allowing the participants' interests to direct the focus.*" This reminder served the purpose to explain once again to volunteers that they are not there to lecture. It helps to remember that a

Figure 4. Hearing Loss station with banner and equipment at 166th meeting of ASA.

volunteer is a guide for the participants personal learning and to focus on participants' specific personal interests that relate to each system and to answer questions in an interactive way.

Guided by the concepts of active learning, we developed hands-on stations tied to 13 different physical systems. This involved first determining which physical systems we would focus on. Second, we took inventory of what demonstration equipment ASA possessed and gathered new equipment to better help each demo tie back to the specific physical principles and learning outcomes. The selection of physical systems was guided by what equipment ASA currently had as well as through experience from BYU's acoustics outreach and BYU's introduction to descriptive acoustics class. Then we organized the equipment by station in protective pelican cases to be ready for transport to and from ASA outreach events. In addition, we labeled each item as belonging to the Acoustical Society of America's outreach efforts as well as with which specific station it belonged to in order to keep equipment more organized.

Since participants are more likely to engage and remember "real things," or what they can relate to, the stations we developed are focused on common real-life physical systems. The stations we developed deal with 13 common physical systems, such as loudspeakers and a variety of musical instruments. To clarify, there are 13 main topics, but several of them have more than one demonstration and can thus be divided into multiple tables when the number of volunteers exceeds 13. In addition, members of ASA are welcome to bring and share their own demonstrations. A list of each station and the equipment used is summarized in Table 1 at the end of the article. Each station, as mentioned, has a corresponding outline. A couple examples are shown in the following figures. The combination of the real-world applications of acoustic principles, interesting demonstrations with updated equipment, and the outlines provided to the volunteers, adds to the order of the stations and focuses them on specific learning outcomes.

Figure 5. Standing Waves station banner and setup at 166th meeting of ASA.

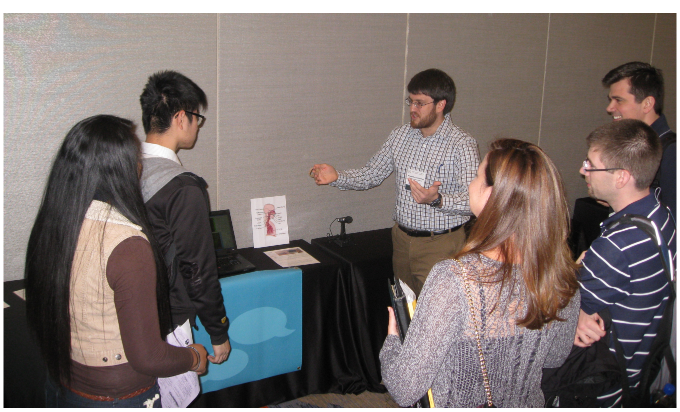

Figure 6. An ASA student member prepared to guide students in learning about the speech production system at the 166th meeting of ASA during the school demonstrations in acoustics session.

As previously mentioned, measures have been taken to seek to build the efficiency of the outreach sessions and increase the ease with which volunteers could assist. Clear explanations, outlines, and organization have all been a part of this. We have also purchased 4 ft. x 2 ft. vinyl banners seen in Figure 3, 4, & 5 with the title and a simple logo for each station to illustrate to participants what they are about to explore. The banners, along with the video introduction help prep the participants for learning. These banners also add to the professional look of each of the stations.

Another important aspect of preparing the students to learn is the introduction of the volunteers following the introductory presentation. This helps participants understand who the volunteers are and initiate a relationship of trust with these professionals in acoustics. This also helps build participants' excitement knowing a little about the specific area of acoustics each volunteer is working in. With this, we believe volunteers will have more confidence and the participants can know who to ask more specific questions they may have regarding acoustics.

We also worked toward the general efficacy of both outreach sessions by uniting them together in a more streamlined program. To accomplish this, all parties involved in running each of the sessions met and collaborated plans, equipment, and efforts which helped to unite all our goals and accomplishments in improving the outreach sessions for the Acoustical Society of America. We combined all the equipment owned by the Acoustical Society of America, which was gathered from different locations and then organized as previously mentioned. We agreed to use the same general format, equipment, and even schedule sessions on the same day and in the same room. All parties recognized that by doing so we would ease the management of the outreach sessions for all involved in the future.

CONCLUSION

The initial reactions of students and of ASA member volunteers have been very positive. The students who attended the 166th ASA meeting were from local high school physics classes. Some students who previously thought physics was boring and uninteresting expressed their newfound enjoyment and excitement for physics, especially emphasizing in acoustics, by the end of the outreach session. Other students made connections with professionals to receive information regarding and potentially funding for higher education. Students generally expressed appreciation and enjoyment for the opportunity to learn about sound and be able to understand their world better through their increased understanding of sound related to the 13 physical systems. The member volunteers who had participated in previous school outreach sessions expressed great appreciation for all that had been accomplished to improve upon the stations and the organization. Other members who had not previously participated were impressed by the success they saw the session could have in bringing STEM enthusiasm to local youth. Regarding session organization and coordination, unifying the content of the two ASA outreach sessions reduces the setup and takedown time. It also further limits possibilities for equipment to be lost and ease the workload of planning and carrying out the sessions by allowing the work to be shared and utilizing the same format.

While much has been accomplished towards the main goals, the outreach sessions are still works in progress. In the future, new demonstrations can be added, current demonstrations can be refined and other acoustical systems or processes could be emphasized to further improve future outreach sessions. Current outlines and more information about the current state of the outreach efforts can be obtained by emailing the authors. The gathering, organization and preparing of volunteers also has room to be improved upon. We hope that there will be continued improvements to the outreach sessions to keep the efficacy of the program. We also hope that the continuation of this program through future ASA members will be eased by our efforts.

ACKNOWLEDGMENTS

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Figure 7. Speech station presenter outline used at the 166th meeting of ASA in the school demonstrations in acoustics session.

Speech

Equipment:

Rubber bands

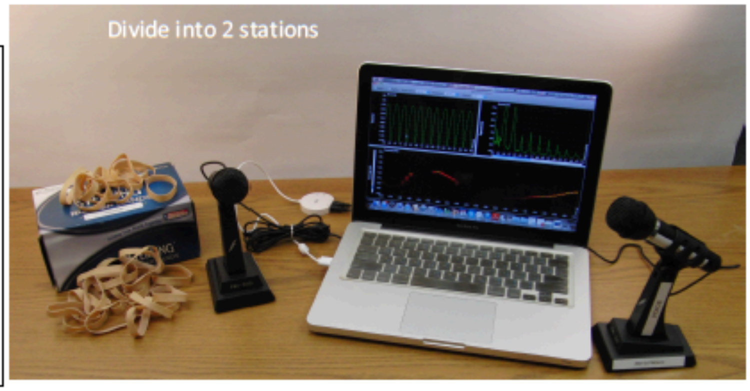
Laptop with waveform viewer and spectrogram

Stroboscope video clip

Oscilloscope/ spectrogram

Microphone

Diagram of human noise production system



Engage audience for approx. 5 min. by exploring the topic together by asking questions and allowing the participants' interests to direct the focus.

Station 1: Vocal folds

What's the process for making speech sounds? *Show diagram of speech anatomy and talk about the parts.*

What do the vocal folds do? *Feel vibrations of Adam's apple for voiced speech sounds and lack of vibrations for unvoiced sounds*

How do the vocal folds make different pitches/frequencies? *Demonstrate the change in plucking frequency on a rubber band for changes in tension and mass per unit length with the rubber bands (give one to each participant) and relate these to the mass-spring systems in the Resonance station.*

Station 2: Vocal Tract

Explain that the vocal folds generate the sound but changing the vocal tract is what makes the different speech sounds.

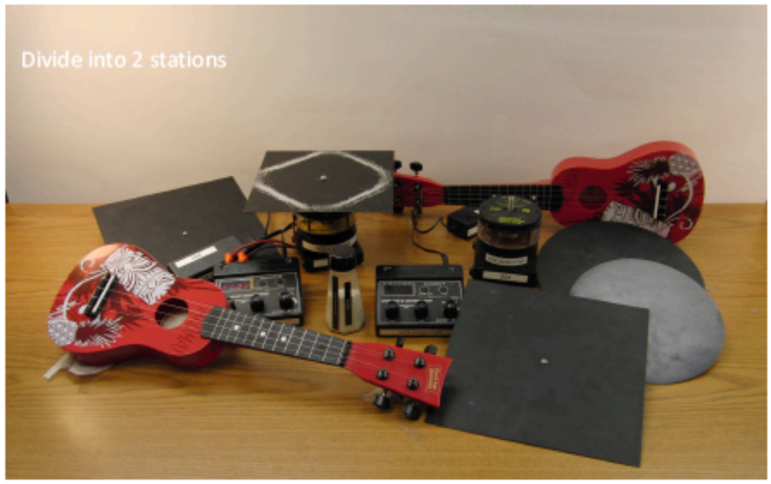
What is your vocal tract? What are you doing with it when you make the different vowels? *Have them try it.*

Look at speech waveforms and spectrograms of vowels and other phonemes. What is the same and different?

Do you know anyone who reads lips? How does that work? Is it ever confusing? *Try "marry" and "bury"*

Figure 8. Violin & Guitar station presenter outline used at the 166th meeting of ASA in the school demonstrations in acoustics session.

Violin/ Guitar



Equipment:

Pasco Shaker (x2)

Sine wave generator (x2)

Chaldni plate (x5)

Sand

Slide guitar(x2)

Ukulele (x2)

Stereo banana connector

Engage audience for approx. 5 min. by exploring the topic together by asking questions and allowing the participants' interests to direct the focus.

Station 1: Ukulele

Does anyone know how to play a string instrument? How do they work?

What is the difference between the sound produced when a string instrument is bowed vs. plucked?

How do you play different notes on a string instrument? *Demonstrate with ukulele.*

What are different ways are to change the pitch being played by a string instrument?

How do you tune a string instrument? *Demonstrate with ukulele.*

How does the body of the instrument affect the sound? *Resonances of the body change the sound.*

Station 2: Chladni plates

Use chaldni plate to show how the body of a string instrument has multiple natural frequencies/resonances.

Explain that the salt falls into the nodal lines – places that aren't moving, like they saw with the standing waves on the slinkies.

Table 1. List of stations, demonstrations used, and short explanations of how to use each

Station Title	Demonstration	General Physics Concepts
Standing Waves	Long thin spring	Making standing waves.
	Small Slinkies	
	Pasco driver & sine wave generator	
Resonances	Mass-spring set	Show difference in natural frequency for various mass-spring combinations.
	Ames tube w/ tuning forks	Show difference in sound generation of tuning fork and Ames tube.
	Crystal glasses	Excite resonances in objects.
	Glass bottles	Show difference in resonance due to volume and neck.
Reflections	Ripple Tank	View wave interaction.
Echolocation	Laser Pointer & mirror	Observe angle of incidence and reflection.
	Hypersonic Speaker	Listen to sound reflections. Example of echolocation.
	Illustrations of bats/dolphins/ SONAR/RADAR	Show real-world connections.
Voice	Box of Rubber Bands	Illustrate changes in the vocal folds responsible for the fundamental frequency of the voice.
	Laptop w/ Oscilloscope/Spectrogram/microphone	View waveform associated with differenct speech sounds. Vowels are periodic and fricatives are nonperiodic.View fundamentals and formants associated with different speech.
	Diagram of human noise production system	Illustrate the parts of the voice production system.
Hearing	Illustrations of anatomy of the ear	Illustrate the parts of the ear.
	A few short boomwackers	Hear difference between open/closed tube.

	Laptop that can play YouTube video of the basilar membrane	Show how the basilar membrane responds to different frequencies.
Hearing loss	Laptop/NASA Auditory demo DVD	Illustrate average hearing loss with age.
	Sound level meters	Quantify loudness and connect what is too loud to real life experiences.
	Ear plugs	Show how to properly wear hearing protection.
Noise Control	Bose noise cancelling headphones	Demonstrate the benefits of noise cancellation.
	Music box demo	Demonstrate the what transmits vibrations and what absorbs.
Piano/Dulcimer	Backpack Hammered Dulcimer	Show relationship of string length and pitch.
	Spectrum analyser	Show how hard hammers have a brighter sound than soft hammers.
Violin/Guitar	Slide Guitars	Demonstrate how tension effects pitch and show how instrument bodies resonate.
	Ukulele	
	Chladni Plates	
Wind/Brass Instruments	Boomwackers	Illustrate the resonance due to length of pipes.
	Recorders	Apply the concept of resonance changes due to length of a pipe with instruments.
Electronic Music	Theremin	Have participants make electronic music.
	Laptop w/ Audacity or garage band and Oscilloscope/spectrogram	Show how electronic music works and how versatile it can be.
Loudspeakers	Surface mount vibration speaker	Explore what materials transfer good vibrations into acoustic signals.
	Loudspeaker in box demo	Show the effect of a baffle on a speaker.
	Illustration of loudspeaker cutaway	View the components of a loudspeaker.

APPENDIX B: THE PHYSICS TEACHER SUBMITION, 2015

Acoustics for the Deaf: Can you see me now?

Although acoustics examples and demonstrations can be an effective tool for engaging students in introductory physics classes and outreach,[1] teaching principles of sound and vibration to the deaf and hard of hearing needs to be approached carefully. The deaf and hard of hearing have less intuition with sound but are no strangers to some of the effects of pressure, vibrations, and other basic principles that are related to sound. We recently expanded our "Sounds to Astound"[2] outreach program and developed an acoustics demonstration program for 80 visiting deaf students. Both this experience, which had a "See and Feel" approach, similar to what was proposed by Lang,[3] and a specialized planetarium program[4] helped reinforce for the students the opportunities that exist for them in higher education. This paper describes some of the pedagogical underpinnings, the demonstrations, their implementation and lessons learned, and student responses.

PEDAGOGY

See and Feel

The Hear and See methodology[5-7] has been used as a means of enhancing pedagogy by focusing on the two strongest learning senses, but this does not apply to deaf or hard of hearing students. Because deaf students' prior nonaural experiences with sound will vary significantly from those of students with typical hearing, different methods must be used to build understanding. However, the sensory-focused pedagogical principle[8] can be applied in a different way for the deaf by utilizing the senses of touch and sight and applying a "See and Feel" method. To employ "See and Feel" pedagogy, it is crucial that the students can clearly see the presenters, interpreters, and demonstrations. Whenever possible students were asked to participate in a demonstration to physically observe the acoustic principle being taught. These practices are consistent with effective pedagogy for the deaf and hard of hearing.[9,10]

American Sign Language (ASL)

In developing the "See and Feel" approach, a fundamental consideration is to select the principles of sound that not only could be seen and felt, but also communicated using words that exist and are commonly used in ASL. In one ASL vernacular, the word for "sound" is a combination of the words "ear" and "shake" (or vibration). The word "pressure" is common, while the word "wave" is uncommon to the point it does not appear in two of the most common ASL dictionaries.[11,12] Additionally, the sign for "wave" is closely associated with a water wave, which could lead to confusion about the nature of sound as a longitudinal wave. Because there is not an ASL sign for "resonance," the nature of sound was taught by focusing on the signs for "vibration" and "pressure." Additional vocabulary, i.e., mode, amplitude, node, antinode, and wave propagation, were presented using classifiers and finger spelling the words.[13]

Students' understanding and retention is improved when the material is taught directly in their native language.[13,14] Consequently, a physics undergraduate student who was trained in both the "Sounds to Astound" outreach program and in ASL was selected to be the primary presenter, with non-ASL-speaking "Sounds to Astound" students assisting. Two bilingual teaching approaches were tried to make ASL the primary instruction language also enabling communication among the demonstrators. In the first approach, the presenter used ASL and spoken English simultaneously. In the second approach, the presenter used only ASL and other interpreters provided a spoken English translation. The second approach proved to be more effective for both the audience and the presenters because it allowed the presenter to focus on describing the principles in ASL, resulting in a better presentation flow for the deaf students.

DEMONSTRATIONS

Once the focus on pressure and vibrations was established, demonstrations that best fit the "See and Feel" approach were selected. A complete list of the demonstrations used, references to the materials and principles taught, and video of the event can be found on sounds.byu.edu or by contacting the authors.

Seeing Sound

To help the students see vibrations, a strobe light was used to "freeze" standing waves on a string by matching the frequency of string oscillations with the frequency of the strobe light. With this demonstration, the relationship of wavelength and frequency were observed as well as other properties of one-dimensional standing waves, such as modes, amplitude, nodes, and antinodes. This demonstration was well received due to the nature of its ability to visualize many basic acoustic principles of sound in a very simple and fun manner. Another way to reinforce these concepts in an exciting way is with a Rubens Tube,[15] in which pipe resonances are explored through the one-dimensional visualization of pressure waves with fire.

The students' visual association with sound was strengthened by allowing students to make noises into a wireless microphone connected to a spectrum analyzer software package that was projected onto a large screen. Although many of the participants were initially hesitant to vocally make noises due to the deaf culture's shyness of purposely making audible noises, they enjoyed making random noises, such as clapping, and seeing what it looked like visually broken down. We encouraged them by demonstrating different sounds such as the singing voice, whistling, clapping, snapping, and all sorts of other fun noises. One of the greatest benefits for the students was to see that their voices or the other noises they could make looked the same as everyone else's sounds on the spectrum analyzer.

Feeling Sound

A large loudspeaker playing a 40 Hz signal helped students both see and feel sound. They were able to see the loudspeaker diaphragm oscillating in and out and feel the vibrations in the air produced by the motion if they put their hand close in front of the loudspeaker. A lighted candle placed in front of the loudspeaker provided additional visual evidence of the pressure wave traveling from the speaker. The visual clue of the sound wave was the fluttering of the flame due to this pressure differential. Eventually as the amplitude increased, the flame was extinguished. The students were very excited and surprised to observe this effect and make a connection to the power of sound. Another effective demonstration of vibrational oscillations was a vibrational speaker placed on a table, which radiates sound from the table. Students felt the sound through the vibration of the table. Some students placed the vibrational speaker on their heads, which gave them a personal experience with sound.

The students were also able to feel sound in our reverberation chamber. A large subwoofer was operated at the resonance frequencies of the room. The students were invited to walk around the room to find the locations where the vibrations felt weakest. As the students stood in these positions, they identified the nodal lines of the resonances of the room, which was connected to the standing wave patterns they observed previously with the string demonstration. In addition, the participants enjoyed standing in the corners of the room, where the sound pressure is eight times as strong, and feeling the power of sound vibrations.

LESSONS LEARNED

The experience of sharing acoustics with the deaf and hard of hearing has been remarkable. We have learned a few lessons about what does and doesn't work well. In particular, the ASL communication, the visual instruction, and the accessibility of the demos to all participants can be improved in the following ways.

Clear ASL communication is key to the success of the event. As described above, it is more effective if the main presenter communicates with ASL and someone else, who understands ASL and physics, provides a verbal interpretation for non-ASL volunteers. In addition, the university and the school for the deaf provided one interpreter for every five deaf or hard of hearing students who were in attendance. This ratio of interpreters gave individualized voices for each of the students in attendance, as well as each of the volunteers, as they communicated with one another throughout the event. Another important consideration is that the ASL presenter needs to be visible to all students at all times. Extra thought is required to illuminate the presenter when the demonstrations require low lighting for maximum visual effect.

Many acoustics demonstrations traditionally rely on the perception of sound to understand what is being shown. Care must be taken to provide visual instruction about the vibration for deaf and hard-of-hearing participants who cannot detect the audible clues. This requires the presenters to think creatively about how to modify demos. For example, when vibrating a Chladni plate, a traditional audience can hear how the pitch of vibrations corresponds to the mode pattern displayed. For a deaf and hard of hearing audience, an accelerometer on Chladni plate whose output is displayed on a screen would provide analogous visual information about the frequency of the oscillations.

In the future, we plan to look into the idea of dividing students into smaller groups for part of the time, to allow each student to interact with each of the demonstrations. This hands-on approach will improve the students' ability to "See & Feel" the principles of sound being illustrated in the demonstrations and benefit more fully from the event. [Error! Bookmark not defined.] Prior traditional outreach efforts[5,16] have initiated the practice of having groups of about 3-4 students visit hands-on demonstration stations and interact personally with the volunteers to increase student engagement and active learning.

By the end of the event, students were participating more freely and asking questions and were very excited about what they had learned. They left with a better understanding of principles of acoustics and how sound affects their lives. The major benefit, however, was providing opportunities for deaf children to see that resources exist for them at universities that will help them succeed in higher education.

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