By Teaching, We Learn – Creating Video Demonstrations of Simple Acoustic Principles to Facilitate Learning

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Abstract — The University of Hartford offers two unique programs in the field of acoustics; a Bachelor of Science in Mechanical Engineering with acoustics concentration and a Bachelor of Science in Engineering with a major in acoustical engineering and music. Owing to the unique nature of these programs, faculty are often asked to give lectures on the topic to prospective students or other interested parties. The author has also delivered a number of Teen Science Café talks in the greater Hartford area. Teen Science Café programs are a free way for teens to explore the big advances in science and technology affecting their lives. There are a number of acoustic demonstrations that would engage and excite a High School audience, but are not suitable for a live setting – for example some involve fire and lasers. This paper describes the creation of five video demonstrations of some basic (but exciting) acoustic experiments. All video demonstrations were developed, recorded and edited by current undergraduate students, in a controlled and safe setting under faculty supervision. The development of these videos also offered current undergraduate students a chance to delve deeper into some basic acoustics principles (Docendo discimus; ‘By teaching, we learn’).

Index Terms - active learning, acoustics, demonstrations, engagement, video.

I. INTRODUCTION

It is well established that active learning enhances engineering education, with considerable literature addressing the advantages of integrating hands-on experiences in an engineering curriculum. Research on the benefits of active learning demonstrates that in addition to achieving learning objectives related to content, students develop abilities in communication, leadership, ethical decision making and critical thinking [1].

The field of acoustical engineering is no different. Many authors have reported on simple experiments they have conducted in the classroom to engage students [2,3] – the Acoustical Society of America (ASA) even has a Technical Committee devoted to Education in Acoustics, and this committee generally organize a session specifically devoted to hand on demonstrations involving acoustics at national ASA meetings. Such demonstrations would also excite a High School student audience and engage them in the STEM field of acoustics, however not all experiments may be easily transported to off-campus locations. For example, the Reubens’ tube, a common demonstration of sound waves and pressure, involves a flammable gas, while another common experiment uses a laser Doppler vibrometer to show how vibrating surfaces may be used to capture audio.

An alternative to these live demonstrations is to show pre-recorded videos of the demonstration, along with some additional background information. Instead of faculty members developing these videos, this paper reports on a recent initiative at the University of Hartford, where undergraduate students developed and recorded all videos. The initiative serves the dual purpose of engaging the undergraduate students in an active manner, as well as providing a resource for lay-people interested in acoustics (including high school students considering further education in the field).

The undergraduate students who developed the videos showed significant engagement in the content; they became teachers, if only for a short while. This type of active learning exercise is an example of an initiative that allows students develop a deeper understanding of the material they are presenting. Learning is strongest when the learner is actively involved in the creation of understanding, and the application of understanding to real problems, and this exercise provided such an opportunity to achieve this.

A. Acoustical Engineering at the University of Hartford

The University of Hartford offers two unique programs in the field of acoustics; a Bachelor of Science in Mechanical Engineering with acoustics concentration and a Bachelor of Science in Engineering with a major in acoustical engineering and music. The program includes a dedicated acoustics laboratory including a reverberation room and adjacent anechoic chamber. These testing facilities, along with a wide array of acoustic and vibration testing capabilities, allow undergraduate acoustical engineering students to work on a variety of real-world acoustic design and research problems. Some of these facilities were used in the development of the demonstrations described in this paper.

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B. Relevance to Acoustical Engineering Education

In 2010 the Committee on Technology for a Quieter America (National Research Council) released a ‘State of the Nation’ type assessment of noise in the U.S. and concluded that the nation needs to educate more specialists in the field of noise control as well as providing basic knowledge of the principles of noise control to individuals trained as specialists in other engineering disciplines [4]. This project directly addresses this need by focusing on some basic acoustic principals that will educate the next generation of noise control engineers.

Furthermore, owing to the interdisciplinary teams working on this project, the research also addresses the ABET learning outcomes (h) ‘the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context’ and (j) ‘a knowledge of contemporary issues’.

C. General Outreach

Very often details related to acoustics gets lost in the technical details: the noise indicators, the decibel scale, the modelling and measurement procedures, etc. The details are, of course, very important, but emphasizing only the technical nature of the science risks alienating a lay audience interested in learning more. This is especially relevant in acoustics, as almost everyone has an intuitive understanding of what ‘sound’ is - we all experience it on a daily basis! Thus, the videos created for this project will likely have a reach far beyond the classroom, and potentially serve a much wider audience as a general information resource.

II. SOME BASIC ACOUSTIC PRINCIPLES

What follows is a summary of some basic acoustic principles that are easily explained with some demonstrations.

A. The Speed of Sound

The speed of sound, \( c \), is the distance travelled by a sound wave per unit time as it propagates through a medium. For sound waves in air, the speed of sound is usually somewhere between 330 m/s and 340 m/s. It varies with air temperature and may be calculated from

\[
    c = 331 + 0.6T \quad (1)
\]

where \( T \) is the temperature of the air in degrees Celsius. The speed of sound can be observed in practice by measuring the time delay between observing an event (e.g. a rocket launch, a starting pistol), and hearing that event.

B. Waveforms

Sound travels in the form of a wave, and is usually depicted as a simple sine wave (Fig. 1). This figure may be used to illustrate basic principles such as frequency, wavelength and amplitude. However, the graph is essentially a representation of a transverse waveform, whereas sound travels as a longitudinal wave. However, the same theory holds, and some simple demonstrations involving waveforms can clarify the relationships to a lay audience.

C. Sound and Pressure

Sound is the result of pressure variations in a medium – typically air. Thus sound can cause localized changes in pressure which can be demonstrated with a variety of experiments. Two classic examples that make use of this relationship include the Rijke tube (a simple demonstration of a thermoacoustic phenomena) and the Reubens’ Tube, (an apparatus that displays the properties of standing waves).

D. Resonance

All bodies that have a mass and elasticity have a natural frequency. This is the frequency at which a system will vibrate once it has been set in motion (e.g. with an initial disturbance like a push or tap). Resonance occurs when a system is excited at its natural frequency. When this occurs the amplitude of oscillation of the system can increase significantly, often with devastating consequences, such as the fall of the Tacoma Narrows Bridge in 1940.

By tapping a wine glass, the natural frequency may be determined by listening to the frequency of the ‘ring’ of the wine glass. If a loudspeaker is used to create a sound at this specific frequency, (or perhaps a talented singer singing the correct note), the wine glass may be caused to shatter. This is a classic demonstration involving the phenomenon of resonance.

III. EXAMPLE VIDEO DEMONSTRATIONS

A. The Speed of Sound & Sonic Booms

The first video created for this project used the world’s most powerful rocket, SpaceX’s Falcon Heavy, as a teaching aid. This rocket was launched from the Kennedy Space Center in Cape Canaveral Florida on February 6th, and two students travelled to Florida to record results related to the speed of sound and sonic booms.

Fig. 1. Simple representation of wave motion.

Fig. 2. Screenshot of students explaining theory related to the speed of sound for video demonstration.
The student team created a video describing the speed of sound (Fig. 2), as well as the basic principle behind the cause of a sonic boom (Fig. 3), and recorded results on site. They measured the time delay between observing the rocket launch and hearing it, and in doing so validated the theory presented in (1).

B. The Rubens’ Tube

The Rubens’ tube is an ideal visual demonstration of sound waves and pressure. It involves a length of pipe, with evenly spaced small holes drilled along the top and sealed at both ends. One seal is attached to a small speaker, the other to a supply of flammable gas. The pipe is filled with gas and the gas leaking from the perforations is lit. This will yield multiple flames, each of the same size, at each of the perforations in the tube.

The speaker is then turned on to produce a sine wave, at an appropriate frequency to create a standing wave in the tube. The standing wave will yield nodes and anti-nodes (areas of minimum and maximum disturbance) along the length of the tube. Where there is maximum pressure, more gas is forced out of the tube, and at this point the flame grows higher. Where there is minimum pressure, there will be little or no flame. It is even possible to determine the wavelength of the sound by simply measuring the distances between the peaks of flame with a ruler. For this initiative, both 1D and 2D Rubens’ tubes were developed.

C. A ‘Laser Microphone’

In order to understand this concept, viewers are first given a quick summary of the workings of a simple microphone. In short, sound travels as a longitudinal pressure wave and this wave vibrates the diaphragm of a microphone (Fig. 5), which then gets converted into an electrical signal that can be played back as sound. Using a laser, it is possible to optically measure the vibrations on any surface, excited by sound, which can then be converted into an electrical signal.

This demonstration shows the laser focused on a piece of paper, with a subject speaking into it (Fig. 6). A laser Doppler vibrometer is then used to measure the vibration of this paper and the acquired signal is converted into sound. The voice of the subject is then reproduced for the video demonstration.

IV. ENGAGEMENT SURVEY

In an effort to measure the level of engagement of the students participating in the development of videos, a simple online survey was administered. Students were invited to anonymously consider five simple items related to the project. The survey was presented in the form of statements, in a manner similar to [5].

Students were asked to rate to what extent they agreed with these statements, on a scale from one to five, where one meant they completely disagreed and five that they completely agreed. The statements presented in the survey, and the average rating each statement received is presented in Table 1.

Overall the results suggest a positive level of engagement. Students embraced the concept of the video making and produced high quality videos that may be used to explain some simple acoustic principles quite well to a lay audience. Perhaps most significantly is the fact that all students surveyed reported that they discussed the content with their peers outside of scheduled hours, indicating a high level of engagement with the content.
VI. CONCLUDING REMARKS

This paper presents a summary of a project that invited undergraduate students to make video demonstrations explaining some basic principles of acoustics. The videos are primarily aimed at students who are considering pursuing further education in the field, but anyone interested in acoustics may enjoy them.

These videos also gave current undergraduate students an opportunity to delve deeper into each of the basic principles described. By documenting these on camera, students were more engaged with the theory behind the principle and made sure to understand the theory and a much deeper level than usually expected. Survey results indicate that students were very much engaged with the content.

It is hoped that this exercise will continue into future years. Overall student enjoyed making these videos, and they each contribute to a library of videos that can be used to encourage students to pursue further studies in a STEM related field.

REFERENCES


Eoin A. King received a B.A. B.A.I. degree in mechanical engineering in 2003, and a Ph.D. degree in mechanical engineering in 2008, both from Trinity College Dublin, Ireland. He is currently an Assistant Professor of Mechanical Engineering, with a concentration in Acoustics, at the University of Hartford, USA. He is a member of the board of the Institute of Noise Control Engineering USA, and serves as Managing Editor of Noise/News International.

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