Introduction to Acoustics Course Development

A Major Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science in Physics

Rhys Forster
May 2023

Abstract

Acoustics engineering is a branch of mechanical engineering that combines theoretical mathematics and physics theories with hardware applications. It rose to prominence in the 1940s and 1950s as a serious field of engineering, in part due to texts like the 1954 book *Acoustics* by Dr. Leo Beranek. In the past few decades, many advances have furthered the connection of acoustics to manufacturing and architectural engineering, wave and sound physics, and medical sciences like audiology. As such, acoustics is a prominent area of study in the modern era. Currently, Worcester Polytechnic Institute does not have a course specifically dedicated to the study of acoustical engineering, thus this project was created to begin developing a course on the subject for Professor Joe Stabile to teach. There have been a number of students at the university who have expressed interest in such a course, meaning the need for an introductory course to the field is present. In the process of development, I first researched acoustical engineering, closely following the aforementioned *Acoustics*, before creating a number of lecture slides developed for instructing a class. To supplement this, I conducted research on different areas of pedagogy and how they can be applied to teaching science. I then incorporated these principles into my work to create a series of slides that are detailed and easily explainable, while incorporating methods of student cognition and retention.

Key terms: *Pedagogy* — The art, science, or study of education and teaching methods.

Table of Contents

Acknowledgements

Foremost, I would like to thank both of my project advisors, Dr. Rudra Kafle and Professor Joe Stabile, for their guidance on this project. Dr. Kafle gave me excellent insight into the physics aspects of this project, and pointed me in the right direction regarding applications of pedagogy and sources for more information in that area. Professor Stabile started this project initially, and was incredibly helpful in applying my physics knowledge to a mechanical engineering setting, and helping me find sources to further my knowledge there as well. I am extremely grateful to them both, as instructors and as colleagues.

From WPI's staff, I would like to thank Lauren Dana, Thomas "TJ" Noviello, Ben Pollard, and Dr. Izabela Stroe for guiding me in my pursuit of not just the physics field, but physics pedagogy as a potential career after research. Professor Stroe specifically inspired the use of Poll Everywhere as a potential deliverable for this project. During my academic career at WPI, all four of them have guided me in this area and made me open to the science of teaching.

Of WPI's student body, I would like to thank Simon Rees and Brent Reissman for their direct and indirect influence. They both acted as inspiration for the creation of this project and its corresponding deliverables, particularly the writing of this paper.

A posthumous thank you goes to Dr. Richard Feynman for his work in physics pedagogy, and for inspiring me to one day continue work in this field. His work is extremely pleasant to read, combining the intelligence of Hawking with the wit of Vonnegut. I aspire to conduct myself as a physicist as he did. Similarly, a thank you goes to Dr. Leo Beranek, whose most famous textbook was used as the main source during this project.

Finally, I would like to thank the WPI physics department, and WPI as a whole, for the opportunity to work on this project. It has no doubt been an unconventional project, but one I am very proud of, and I am grateful to have been able to work on it.

List of Figures

1.0 Introduction

1.1 Overview

The ultimate purpose of this research project was to develop a teachable course on the subject of acoustics for WPI's mechanical engineering department, to be taught by Professor Joe Stabile. Specifically, the course would outline an introduction to the physics theories, practical applications, and hardware development of acoustical engineering. While the project began as a mechanical engineering MQP, it quickly became clear that much of the groundwork of the course was rooted deeply in physics. General mechanics, electricity, magnetism, and wave theory were all very prevalent in this research, meaning my background in these fields was essential.

The primary source for much of the course's content came from the textbook *Acoustics* by Dr. Leo Beranek.[2] This is a widely used source for all things acoustics, and is often cited as one of the most influential texts in the field. While this is by far not the sole source of information the final course is based on, it was from the division of sections in this book that I derived the topics covered in my slides.

To specify, the purpose of this research was not solely to teach myself the physics of acoustics, but rather to develop this knowledge into a feasible method of teaching the information in a lecture style. As a result, I not only researched the actual mechanical engineering material for the course, but also methods of adapting textbooks into courses, different methods of conveying information to students, effective use of presentation slides, and methods of checking a student's understanding of topics. In this paper I will summarize my findings from this research, and demonstrate how I applied it to this project.

1.2 Objectives

At the beginning of the project I set out a basic outline for what I had wanted to accomplish, which included a series of Microsoft Powerpoint-style slide decks, lecture notes, practical laboratory experiments, and small end-of-class check-in quizzes that would allow students to summarize and reflect on what they had learned from each slide deck. I had originally divided the textbook *Acoustics* into sections based on proposed divisions in the text itself, seen in Figure 1. By dividing the proposed course into topics like electrical circuitry, wave propagation, and hardware, it would be easier to see what was feasible for this project.

Topic	Sections in Beranek	My recommended courses
Circuitry	VI VII VIII IX	PH1121/1120
Propagation of Sound - Impedance	X XI XII XIII	
HARDWARE		
Microphones	XIV XV XVI	
Direct Radiator Loudspeakers	XVII XVIII	
Loudspeaker enclosures	XIX XX	
Horn Loudspeakers	XXI XXII	
Sound in Enclosures	XXIII XXIV XXV	
Noise Control	XXVI XXVII	

Figure 1: The original plan for dividing Dr. Leo Beranek's Acoustics into teachable topics.

I quickly learned that I needed to be more realistic with my time and manpower, being a one-person team. I underestimated the full scope of developing a college-level course, so needed to cut my expectations back a bit. In the end, I made cuts to all sections equally, so as not to lose my original vision of how the course would be developed. I decided to amend my proposed deliverables to include the following:

1. Seven slide decks for lecture-style teaching
2. End-of-section mini quizzes using polleverywhere.com
3. This paper outlining my process of incorporating pedagogical methods into my slides

These deliverables will be explained in greater detail in section **3.3 Deliverables List**.

2.0 Background

2.1 *Acoustics* by Dr. Leo Beranek

Published in 1954, Dr. Leo Beranek's *Acoustics* had been revered as an influential text in its field, especially for the time. Dr. Beranek taught acoustics at Harvard and the Massachusetts Institute of Technology for thirty years, and was a founding member of Bolt, Beranek, and Newman, now Raytheon BBN.[7] While the relevance of some material in *Acoustics* has since become outdated, the vast majority of the book still contains important information regarding air acoustics and sound propagation, as well as technical hardware and other applications to the engineering field.[3] The book is divided into chapters and parts, which in turn were divided into sections with similar themes during the creation of lecture slides.

It is important to highlight this book in particular, as it was the foundation for the development of this course. The book itself contains a proposed breakdown of teaching in its introductory section, which was modified into the final division of topics used in the course.

First Term		Second Term	
Part I.	Introduction	Part V.	Energy Density and Intensity
Part II.	Terminology	Part IX.	Circuit Theorems, Energy and Power
Part III.	The Wave Equation	Part XI.	Directivity Index and Directivity Factor
Part IV.	Solutions of the Wave Equation	Part XIV.	General Characteristics of Microphones
Part VI.	Mechanical Circuits	Part XV.	Pressure Microphones
Part VII.	Acoustical Circuits	Part XVI.	Gradient and Combination Microphones
Part VIII.	Transducers	Part XVIII.	Design Factors Affecting Direct-radiator Loudspeakers
Part X.	Directivity Patterns	Part XX.	Bass Reflex Enclosures
Part XII.	Radiation Impedances	Part XXI.	Horn Driving Units
Part XIII.	Acoustic Elements	Part XXII.	Horns
Part XVII.	Basic Theory of Direct-radiator Loudspeakers		

Figure 2: A section of the proposed division of parts from *Acoustics*.

While not adhering strictly to the "first term second term" approach, this breakdown makes it clear that there are similar parts of *Acoustics* which would pair well and could easily be taught as one section. As such, this introduction was helpful in the planning phase of the project.

2.2 Pedagogy Principles

After researching acoustic theories and applications, the next step was to create teaching tools that would effectively communicate my research thus far. Therefore, I needed to investigate pedagogy principles and their uses in the teaching of science courses. Pedagogy is loosely defined as the science of teaching, and there have been many studies conducted on methods of instructing and their effects on a students relationship with material, and more importantly, their retention of it. The most important principles that I researched and then implemented into my slide decks were that of Multimedia Learning, Spatial Contiguity Principle, Effective Presentation Styles. These all have visible influences when looking at older versions of my slide deliverables, and their applications will be discussed in more detail in section **3.2 Applications of Pedagogy Principles**. For now, I will outline the three aforementioned principles.

2.2.1 Multimedia Learning

Humans are able to take in information using their numerous senses, but the most traditional ways of receiving information are through sight and hearing. These are referred to as “channels” of learning, and can act independently of each other.[6] However, the concept of Multimedia Learning revolves around the combination of these two channels in a balanced way. In its basic form, Multimedia Learning refers to the process of learning from words and pictures, rather than from large blocks of text.[6] If a student is reading a slide consisting of mostly text at the same time as a lecturer is speaking, they are only able to focus on one dialogue at a time. The student is using both their main channels of intake at the same time, with the same amount of dependence. This can lead to too much information being taken in from two different sources.

To resolve this, we can instead focus on the majority of information coming in one channel of learning, while supplementing it with context coming from another. In this case, we would be delivering the majority of information orally for a student to listen to, while representing key ideas with pictures and small amounts of text for students to see. In doing so, we create less confusion of information, leading to better retention.

2.2.2 The Spatial Contiguity Principle

As stated above, Multimedia Learning can be utilized to minimize extraneous confusion in students while processing information given to them. There are many methods of conducting this, but the most important that I discovered was that of the Spatial Contiguity Principle. This states that students learn better when corresponding information is presented side by side, rather than far away. This means that by putting connected information together in the display, students can correlate them quicker than if they were further apart.[6] Information presented in a numbered list, paired with a diagram labeled with corresponding numbers, is less effective than a diagram labeled with the information itself.

This principle hinges on the fact that simple diagrams with direct paths are much easier to follow than those with extra steps. When viewing direct labeling, the brain needs to make fewer connections between the text and the image, meaning that it can create more meaningful ones quicker than when it needs to constantly reference a list. Similarly, it has been found that while both simple and complex diagrams are constructive to cognition and reduced comprehension errors, simplified diagrams more strongly support information retention, and are therefore more beneficial to students.[4] As such, by labeling simple diagrams directly, we can get students to better understand and retain the information being taught.

2.2.3 Effective Presentation Techniques

Finally, an important principle of conveying information is slide design. This comes in multiple forms, as there is an entire autological field of study dedicated to the science of effective presentations. Some elements of this were more applicable to my process of developing my deliverables than others, and these are the ones I will discuss here.

First and foremost, I found that slides need to be well organized, but engaging. Clean slides with little embellishments and distractions lead to greater retention, but plain slides can lead to boredom and loss of attention. By balancing these two principles, we are able to create slides that engage an audience while not distracting them from the information being presented.

To follow this, including visual guides is extremely useful, while steering away from textual information. Visuals have been found to increase audience engagement and retention: two blocks of text or even two sets of bullet point breakdowns of information are not visually different from each other in any way besides content. However, two images are very noticeably different, and can be easily distinguished, leading to separation of ideas.[9] As such, visual learning is very useful, and far superior to text-based presentation.

Another aspect of effective presentations is connecting with your audience. A method of this is by telling a story that your audience can follow. This can lead to your audience relating with different areas of the topic due to their own personal experiences. Similarly, this can lead to conversations between the audience and the presenter.[9] By treating a presentation as a conversation, this lets audience members participate in discussion and share their own opinions, strengthening their connection with the material.

These methods of creating an engaging, memorable presentation can all be applied to an educational setting, as passing information to students and having those students retain said information is the whole purpose.

2.3 Student Check-Ins

Through both my pedagogy research and personal observation of my professors at WPI, I discovered that an effective principle is the use of check-ins throughout lectures. Incorporating time to ask students questions about the material covered immediately after covering it is extremely useful, and I have seen its positive effects first-hand as a student. This method works twofold: first to summarize the information taught in a lecture, and second to test a student's understanding of the material. In doing so, an instructor can better evaluate their class' retention of the information. In response to student engagement, the instructor can then play an active role in solving their student's problems by addressing concerns as they appear.

2.3.1 Importance of Check-Ins

Having quizzes in a classroom environment has been found to be extremely beneficial.[5] They can be linked to greater metacognition of a subject, as well as giving students time to reflect on their learning.[1] It has been found that by prompting students to evaluate their learning as they go along is extremely beneficial to their understanding. This principle of "thinking about thinking" can lead not only to greater retention of material, but also to higher-level thinking that leads students to further learning.[5] Also, interactive experiences have been found to be more memorable among students, meaning that their inclusion in a lecture can lead to further retention.[9]

To the contrary, graded quizzes can cause stress in students, leading to negative association with material. Grades are often perceived as high stakes items, meaning that anything jeopardizing them will be stressful and perceived as a punishment. If students are tested on material with this philosophy, they will associate the negative stress of a decreasing grade with the material covered, leading to retention issues and an overall apathy towards the subject.[8]

To compromise these two points, I have found that implementing frequent, ungraded quizzes into lectures can provide an appropriate outlet for both testing student understanding and letting students reflect on their studies. This combines the positive reinforcement that comes from testing knowledge and discussing shortcomings, while removing the perceived threat of punishment by not making them graded work.

2.3.2 Using PollEverywhere

In my experience, the best method to create such quizzes is using Poll Everywhere, a free-to-use website that allows users to create their own polls. I have used this website in the past, both for personal use as a creator and as a student in a classroom setting. The use of the website revolves around presenting a set of questions that, while active, can be answered remotely and anonymously by participants using either a computer or smart device. This also means that participation is not restricted to one type of device, as it is accessed through the internet, and can be done so using PC, Mac, iOS, Android, and many other device software.

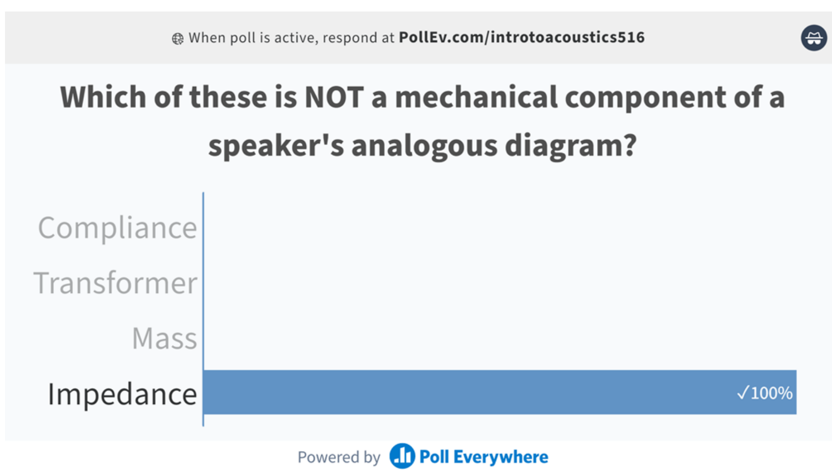

Figure 3: The presentation view of a question on Poll Everywhere.

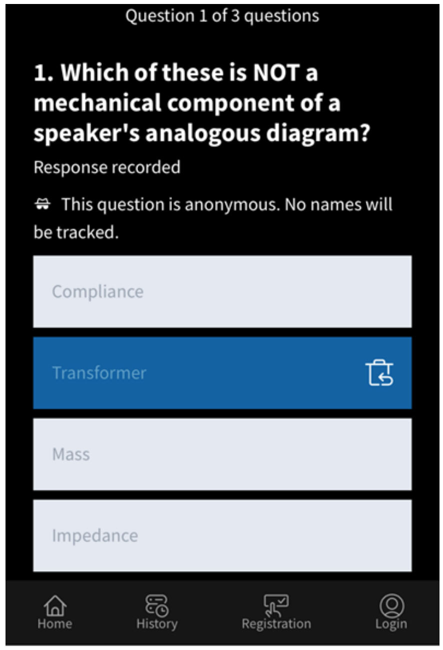

Figure 4: The corresponding user view using a smart device.

Poll Everywhere allows creators to include multiple choice, short response, and true or false questions in a survey format, which can be presented one at a time for participants. Each question also appears on the user's device. There are options to show correct answers after an allotted time, letting the presenter address the responses as they come up. This means that for each section discussed, a presenter can pose questions to the student audience, collect responses, and address any shortcomings in student retention of material. On the student side, they are able to directly engage with the presentation, have their understanding tested, and then reflect on what they have learned or where they may need to work on. Poll Everywhere allows all of this to happen cleanly, efficiently, and for free, making it an extremely useful tool for this course.

3.0 Methods

3.1 Division of Topics

As mentioned, the division of topics was essential for creating a balanced set of lecture slides. If a slide deck contains too much information, then it is unlikely that students will learn and retain such a large amount of information in one sitting. This does not necessarily happen when slides are short, but for simplicity's sake, finding the right length for lectures is necessary. Thus, it was important to combine the sections of *Acoustics* appropriately. The final division of content for each slide deck is as follows:

Lecture Name	**Parts in *Acoustics***
01 Introduction	I, II
02 1D Derivation	III,
03 Solving the Wave Equation	IV
04 Analogies	VI, VII, VIII, XIII
05 Direct Radiator Loudspeakers	XVII, XVIII
06 Horn Loudspeakers	XXI, XXII
07 Loudspeakers in Enclosures	XIX, XX

Figure 5: The final list of lecture topics and their appropriate parts in Acoustics.

Slide set 01 Introduction contains an introductory history of acoustics as a science, as well as introduces properties of sound. It begins with the origins of the study of acoustics, then transitions to an outline of the course, and concludes by covering the way sound is generated, the pressure equation, and the properties of sound propagating through gas. This section puts notable emphasis on the image of a diaphragm vibrating, physically pushing air out of the way, which comes up often in later sections. Laying the groundwork here will make later sections easier to understand.

Slide set 02 1D Derivation and set 03 Solving the Wave Equation are closely linked, as they both deal with introducing the one-dimensional wave equation and its applications to acoustics. The former entirely consists of a breakdown of deriving the wave equation into a partial derivative form, in doing so combining equations pertaining to motion, gas, and continuity. This step-by-step process allows students to see where the final equation came from, rather than simply stating the final equation. This is done in order to connect physical properties they may already be aware of, such as the Ideal Gas Law, to the theoretical mathematics of the wave equation.

The second set of wave equation slides, 03 Solving the Wave Equation, takes this a step further by demonstrating how to apply the equation to the field of acoustics. This involves creating a general form of the equation, solving this form for given parameters, and equating this new form with the physical phenomena of sound wave propagation. This is a noticeably smaller section compared to the other slide decks, as it was more important to address the upcoming parts of the course. This is an area that could easily be expanded in the future.

The next set of slides, 04 Analogies, is quite the opposite. The largest set of slides, it introduces the concept of analogous systems, which is essential for the modeling of acoustic hardware like loudspeakers and enclosures. Such hardware contains elements in three domains: electrical, mechanical, and acoustical. In order to display these three domains in one diagram, we must introduce the concept of analogous systems. This states that a certain property of one domain that shares similar modeling equations and characteristics with a property in another domain can be displayed as such. More specifically, we can use electrical diagrams to model not just electrical components, but mechanical and acoustical components as well. The following diagram, taken from 07 Loudspeaker Enclosures demonstrates this:

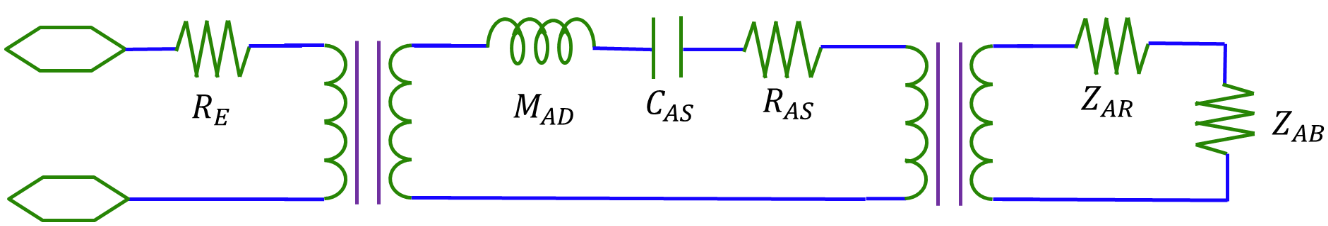

Figure 6: The analogous circuit for a loudspeaker in an enclosure.

This is a concept that is revisited frequently when hardware components are introduced in the next three sections, and as such needs its own dedicated section. While dense content-wise, this section relied on several diagrams, and ended up taking the longest to create as a result.

The remainder of the lecture slides pivot to more mechanical engineering oriented topics. While the previous topics mostly dealt with physics properties or theoretical mathematics, the remaining ones outline applications of the former to physical hardware. To start this off, slide deck 05 Direct Radiator Loudspeakers introduces students to the most basic of acoustic hardware, the direct-radiator loudspeaker. This involves discussing the advantages and disadvantages of this type of speaker, then details the mechanical process of how such speakers turn movement into sound waves. Next, this section discusses the components of a speaker, including information about material engineering when appropriate. Finally, the section concludes with a diagram of the analogous circuit for direct radiator loudspeaker, and explains what properties are at work therein.

Similarly, the penultimate section 06 Horn Loudspeakers deals with a specific kind of loudspeaker with a vocal horn attached. This section is very similar to the previous, as it points out the advantages and disadvantages of the horn loudspeaker, and illustrates in what setting this type is appropriate to use. The added information for these slides is in the discussion of horn mouth and throat ratio, and the importance of horn shape and how it relates to sound propagation efficiency. This returns briefly to theoretical mathematics and physics properties with the inclusion of equations to model these important aspects. To conclude the topic, the slides include a detailed breakdown of the analogous circuit for horn loudspeakers, which builds off of the information established by the circuit in the previous section.

Finally, the last slide section, 07 Loudspeaker Enclosures, builds directly off of 05 Direct Radiator Loudspeakers by putting one such speaker in an enclosure, and detailing the changes that occur. Of note is its return to material engineering when discussing the difference between baffled enclosures and bass reflex enclosures, and how each one is created and appropriately modeled. The analogous circuit for this section is the largest so far, and demonstrates the application of principles learned in the last two slide decks to a new topic.

With an outline of what each slide deck covers, the following list of deliverables will seem more substantial.

3.2 Applications of Pedagogical Research

Due to the way in which I conducted research parallel with developing my slide decks, it was important that I was constantly reviewing my work to incorporate the theories I found. This also allowed me to further demonstrate the importance of these principles using examples of my own work. As such, I will now go over the three aforementioned pedagogy principles and demonstrate examples of their inclusion in my slide deck deliverables.

3.2.1 Incorporating Multimedia Learning

As mentioned, Multimedia Learning boils down to learning with a combination of pictures and text. This was not something I originally incorporated when developing my slides. To begin with, my slides consisted of large areas of text supplemented by a few pictures. The most organized of these slides were those that included bullet points.

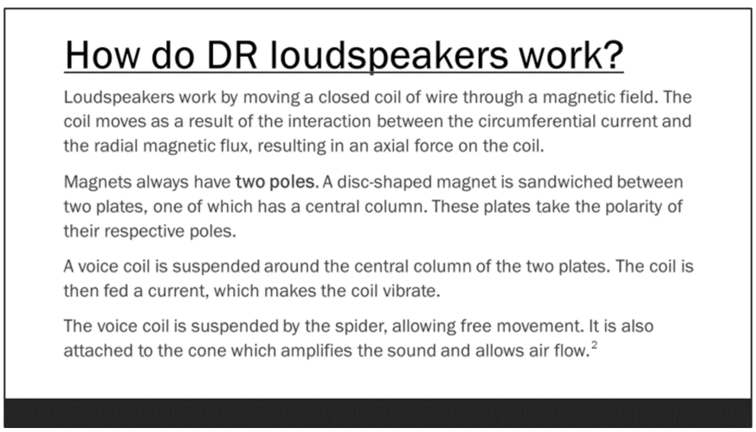

Figure 7: The first iteration of a slide about how Direct Radiator Loudspeakers function.

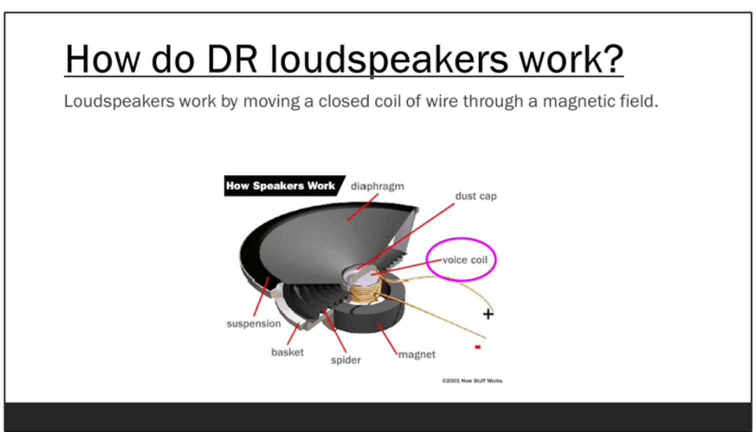

Figure 8: The final iteration of one of many slides that display the same information.

By applying the principles of Multimedia Learning, I decided to divide the information of this slide across five different slides. In this way, I was able to include pictures and labels instead of text blocks. For example, the slides above changed quite a lot due to the application of this principle. Of significant note, I included a moving image of a speaker vibrating as the focal point of these slides. As the presentation goes on, the focus frequently returns to this graphic, not only cementing its importance but also giving viewers a way to ground new knowledge to something familiar. Finally, the Multimedia Learning theory states there should be corresponding labels to accompany the image. These take the form of highlighting key loudspeaker components that are discussed in the subsequent slides.

By editing my existing slides to incorporate the principles of Multimedia Learning, it is clear to see their importance and efficacy in this type of presentation.

3.2.2 Incorporating the Spatial Contiguity Principle

Continuing with the inclusion of diagrams, I moved onto incorporating the Spatial Contiguity Principle. After adding numerous diagrams, it was necessary to not only label them correctly, but also in a manner that aided student learning and cognition. This is highlighted in the following example, where the components of a Horn Loudspeaker are labeled in an exploded diagram. It is clear seeing the difference between a list labeling method and a direct labeling method, as it takes less time to read and react to the latter than it does the former.

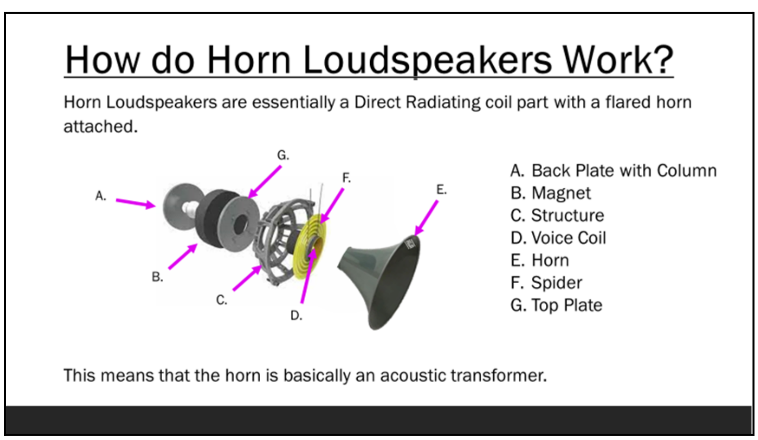

Figure 9: The first iteration of one of many slides about how Horn Loudspeakers work.

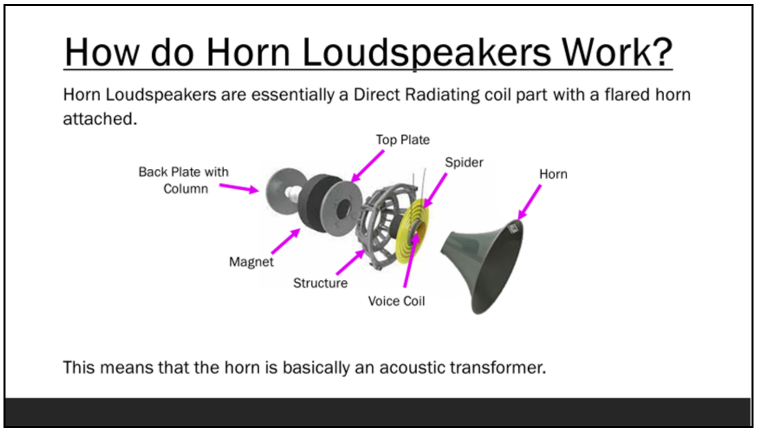

Figure 10: The final iteration of the same slide.

Having a list of components that corresponds to numbered or lettered labels, like in the first example, is detrimental to learning. This structure separates the textual information from its visual counterpart, meaning the brain needs to do more to relate the two and memorize the connection. By labeling each component by name, the text and image are more directly connected, leading to better association and retention.

3.2.3 Incorporating Effective Presentation Techniques

Finally, it was necessary for me to apply my research on the aspects of an effective presentation to all of the slide decks. Most notably, this took the form of adding diagrams, particularly ones that had motion to display concepts like soundwaves and pressure. It was important not to crowd too much information onto one slide, and using diagrams to convey concepts naturally lead to singular slides turning into multiple, as seen between Figures 7 and 8.

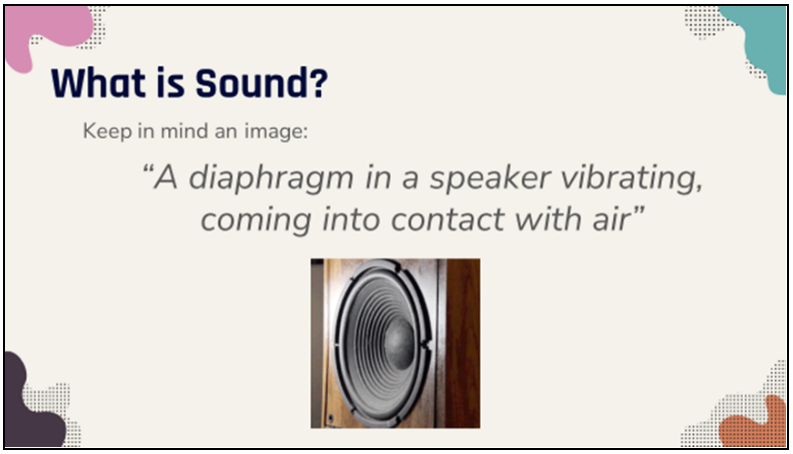

Figure 11: A slide showing the original theme for the slide decks.

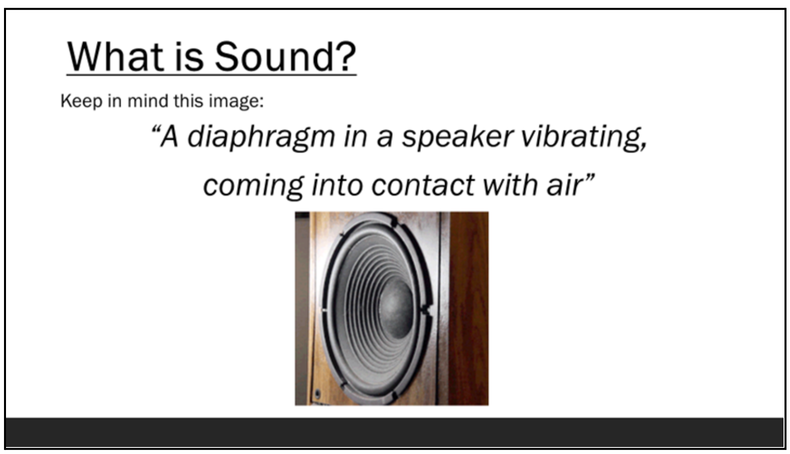

Figure 12: The same slide in the updated theme.

This also meant that I needed to redesign my slides into cleaner, less busy ones. I decided to change my original theme, which was very bright and colorful, but also quite distracting. This led to the more monotone, professional theme that is seen throughout the rest of this paper. While doing so technically made my slides less engaging, as this is an effect of removing color from slides. However, the inclusion of more images and diagrams made up for this, meaning that students were not distracted by unnecessary inclusions, and not bored by unengaging slides.

3.3 Deliverables List

Through the duration of this project, I kept a clear goal in mind for what documents and summaries I wanted to pass on to Professor Stabile and future development teams. These needed to be a cumulative display of both my research in the field of acoustics, as well as my look into pedagogy and its applications to the study of physics and mechanical engineering. As such, the following list of deliverables took shape.

3.3.1 Slide Decks

As mentioned, the bulk of the deliverables for this project is found in the seven slide decks for lecture-style teaching. After all, these are what will be presented to students taking this course, and their content is important. After researching acoustical engineering by reading through *Acoustics* by Dr. Beranek, sources from industry professionals, and other additional materials, I created seven slides based on sections provided in Dr. Beranek's book. The content of these slides have been outlined in great detail in section **3.1 Division of Topics**.

Once these slides were created, it was essential to edit them for both content and simplicity, employing the pedagogy principles discussed in section **2.2 Pedagogy Principles**. Different philosophies of teaching state different things, so by looking at a multitude of methods I was able to cherry pick ideologies that worked well together and with the topic at hand. I believe that the way a topic is taught can greatly influence a student's understanding. Therefore by researching different methods of teaching, I was able to make my slides more digestible for students, which will ideally mean they can retain the information better.

3.3.2 Poll Everywhere Quizzes

To supplement the slides, I created mini quizzes for each of the sections using the website Poll Everywhere. I have been using the word "quiz" to describe these polls, but these are not graded in any way, and are simply used to test the immediate understanding of students. This allows instructors to see where students are struggling in real time, and actively address questions as they are occurring. This method also lets students reflect on what they have learned, if they are confused on a specific topic, and where they can ask for help. In doing so, this gives both the instructor and the students time to address concerns immediately upon occurrence.

On the whole this deliverable usually consists of two quizzes for each slide deck: one placed in the middle of the content and one at the end. This means that students will be introduced to a couple of topics, have their understanding tested, and then continue with more content based on this knowledge. Due to how the slides are written, this usually means that the first quiz is testing understanding of the theories presented in the slides, with the second testing on the practical applications of these theories. In structuring the quizzes like this, we are able to better cement the learning of students.

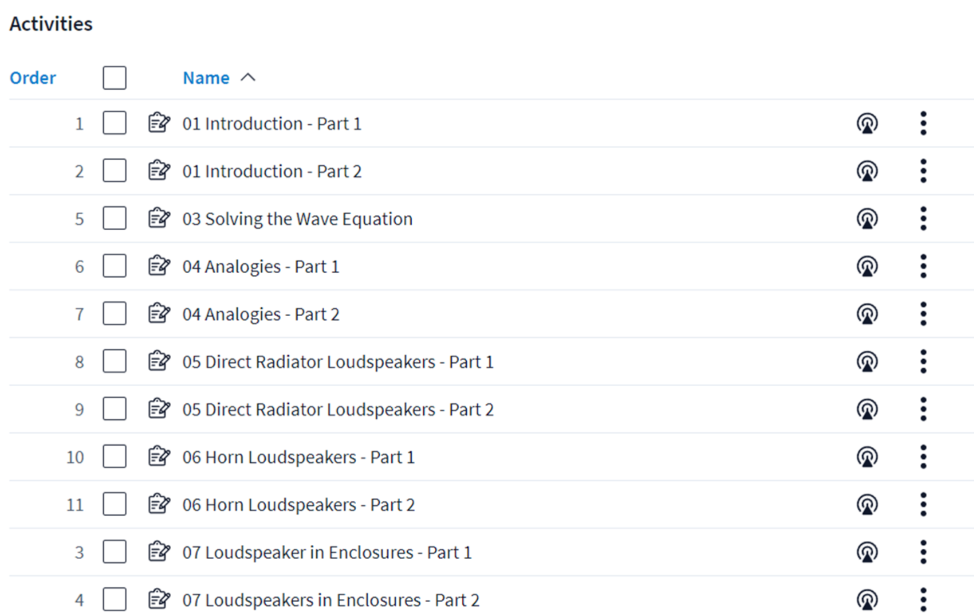

Figure 13: The full list of section quizzes on Poll Everywhere.

In total, I created eleven quizzes of two to three questions each, with room to be expanded upon. I felt that the limit for the number of questions per quiz should be around three. The exercise is not intended to be a full evaluation of a student's knowledge of the course, but rather a check in to determine areas that need immediate improvement. Thus, a smaller number of questions touching on the key ideas of each slide will be more beneficial. I will be giving the information of the Poll Everywhere account that contains these quizzes to Professor Stabile as part of this deliverable.

3.3.3 Summarizing Paper

The final deliverable for this project is this paper itself. More specifically, the background and methodology sections, which outline my research on different pedagogical methods and their applications to teaching science, and their applications to my other deliverables. This acts as both a summary of my findings, as well as my reasoning for incorporating such ideologies into my slides. The paper explains ideas like the importance of the structure of my slides, my decision to include Poll Everywhere in the slides, and my applications of specific principles to specific slides to make them easier to understand and retain. This section will also act as a useful springboard for future groups looking to expand on my work, as I have outlined both the theories I researched and how to include them in teaching acoustics, making the development of more slides in the future easier.

4.0 Conclusion

Obviously, the creation of a course is an extremely large project, and while I would have loved to be able to finish all the content for the course myself, that was never the goal. Instead, I wanted to create a launching platform for future MQP teams to continue from, laying the groundwork with my slide decks acting as a guide for effective lectures, and my pedagogy research demonstrating ways to further the project in the future. In doing so, I made it easier for groups to develop more slides in the style I have developed, using the principles of development and pedagogy I have outlined. At the same time, I wanted to inform them of the importance of including interactive components like the end of section mini quizzes, and set a precedent for more to be made in the same way.

In conclusion, my project incorporated elements of teaching styles and student learning, and added it on top of a background of physics theory and mechanical engineering practice. This culminated in seven sets of lecture slides that are ready for presenting, tested ways of ensuring student success, and the tools to create more. This stands on its own as a project, and allows for further development and completion by more expanded teams.

References

1. Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., & Norman, M.K. (2010). *How learning works: Seven research-based principles for smart teaching*. San Francisco, CA: Jossey-Bass.
2. Beranek. (1993). Acoustics (1993 Edition). Acoustical Society of America.
3. Blackstock, D. T. (1988, March). Review of *Acoustics, 1986 Edition*. *Acoustical Society of America*, *83*(3), 1206–1207.
4. Butcher, K. R. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology*, *98*(1), 182–197. https://doi.org/10.1037/0022-0663.98.1.182
5. Gurung, R. A. R. (2023). *Encouraged students to reflect on and evaluate what they have learned*. IDEA. Retrieved April 20, 2023, from https://www.ideaedu.org/idea-notes-on-instruction/encouraged-students-to-reflect-on-and-evaluate-what-they-have-learned/
6. Mayer, R. E. (2009). *Multimedia Learning* (Second). Cambridge University Press.
7. Rifkin, G. (2016, October 17). Leo Beranek, Acoustics Designer and Internet Pioneer, Dies at 102. *The New York Times*. Retrieved from https://www.nytimes.com/2016/10/18/business/leo-beranek-dead.html.
8. Schinske, J., & Tanner, K. (2014). Teaching More by Grading Less (or Differently). *CBE life sciences education*, *13*(2), 159–166. https://doi.org/10.1187/cbe.cbe-14-03-0054
9. WilmU Edtech Staff. (2023). *The Science of Effective Presentations*. Educational Technology. Retrieved from https://www.wilmu.edu/edtech/documents/the-science-of-effective-presenations---prezi-vs-powerpoint.pdf