Sounds About Right

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Host Organization: Fejer Lab **ETP Type: Classroom**

Subject/Grade: Principles of Engineering/11-12

Abstract (~150 words)

This ETP outlines a three-day lesson, consisting of one 55-minute and two 102-minute block periods, centered around the analysis of audio data. In the first half of the learning sequence, students will learn the mathematical model of waves so that they can extend this knowledge to how we perceive the phenomena of sound waves through musical notes. They will then learn how to assess the quality of a musical instrument by using a phone app, to decompose a sound wave into its respective frequency components. The sequence will develop their familiarity with the tool, culminating in a design challenge where students design a straw flute which can consistently generate three different tones. They will validate their design by using a spectral analysis tool to identify dominant frequencies of their tones.

Focal Content & Supporting Practices

Analyzing and Interpreting Data (*Science and Engineering Practice)*
Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.

Focal Practice
Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.

Additional Practice(s)
Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

21st Century Skills and Applications (1 - 2 bullets)

Employs media and technologies that align with purpose and enhance communication

To apply this skill during the lesson, students will use Google Slides to communicate their findings

Measurable Objective(s)

Students will be able to
1) Identify the average frequency of a tone by analyzing a power spectral density graph.
2) Use data collected from a power spectral density graph to:
    a) Reflect on how well they've made their musical instrument
    b) Provide suggestions for future improvements based on measurements

Formative Assessment(s)

Checks for Understanding (within presentation)

- *MIT Paint Can Oscillator (Is the graph plotted against time or position?)*
- *Components of a Distance vs Time Graph for a Wave*
- *Creating a Graph with the Right Frequency*
- *Placemat for students to plan out how they'll create the slide deck*

Summative Assessment(s)

Students will create a **short slide-deck** that will be evaluated based on a rubric, with emphasis placed on how well they can incorporate their measurements into the evaluation section.

Fellowship Description (300-500 words)

This summer, I am working in the Fejer Group at Stanford University. Research conducted in this group focuses on the nonlinear optical processes which occur when light produces a non-proportional response from the material. Additionally, the lab specializes in ultrafast optics — which operate on the scale of femtoseconds. The understanding gained from the lab has applications such as frequency conversion, which can generate desired light frequencies by leveraging nonlinear optical processes. Another application can be found in high-speed communication systems, where optical parametric amplification, a technique used in the lab, plays a pivotal role.

My fellowship, in particular, revolves around the characterization of a chip produced by a visiting scholar who had previously designed several waveguides on it. I will be collecting and analyzing data so that we can select which device shows the most promise for future investigations. In order to perform this, I will reach a practical understanding of both the underlying theory as well as the instrumentation used to measure the phenomena. From this, I will also use analysis packages to extract various characteristics of the device in order to assess performance and provide feedback for future improvements.

Fellowship Connection to School/Classroom (300-500 words)

Understanding how to evaluate and improve upon one's solution is a fundamental aspect of the Engineering Design Process. This is a core theme in my Principles of Engineering class, where students get exposed to different engineering disciplines. Each unit culminates in a project where students have to quantitatively evaluate their work through calculation or measurement. The experience is supposed to model what professional engineers do on a day-to-day basis — design, construct, evaluate. The content in each of the units varies, but the underlying emphasis does not.

This is not so far removed from what I am currently doing in my fellowship. The light which we generate is composed of different frequency components. In analyzing the energy distribution of a signal after we pass it through a crystal, we are able to determine how efficient our devices were in transforming desired frequencies. I intend to translate this experience to my students by explicitly teaching them how to thoughtfully incorporate data into evaluations. Instead of using optical signals, students will use acoustic signals in the form of musical notes. They will learn to parse a spectral density graph, which splits tones into their respective frequencies. Students will be challenged to create pan flutes only knowing what the notes should be. They will then iterate through their design so that they can showcase the efficacy of their work at the end of the lesson.

Instructional Plan (This is the bulk of your ETP and may take several pages.)

Lesson Plan

Additional Supports
Tools to meet the needs of all learners (SEL, distance learning, ELL, SPED)

To help students plan for their slide decks, a graphic organizer has been included so they can plan.

Materials
Include links to all files within this ETP

Straw Flutes
- **Two-Three Plastic Straws per Student.** *The best ones are the large soda straws so that students can reuse cut off portions to create higher pitches.*
- **Scissors**
- **Audio Spectrum: *Phyphox*** (*Download on your phone through iTunes or Google Play Store)*
    - Descriptive Video
    - Wiki Site for all Experiments

Simulations
1. Water Waves
2. Wave Addition Interactive
3. Sine Wave Sounds
4. Tone Generator

Lesson Materials
1. Lesson Plans
2. Main Presentation
3. Independent Practice
4. Gallery Walk Checkbric
    a. Design Process Placemats

References

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Keywords (2-4)

Waves, Fourier Transform, Frequency Spectrum