Lesson Title	Investigation of Timbre (Sound Quality)
Length of Lesson	2 days
Created By	Jed Leggett, William Funderburk
Subject	Physics
Grade Level	11-12
State Standards	Physics 1b,c,d,f; 4a
DOK Level	4
DOK Application	Design, Analyze, Apply Concepts
National Standards	9-12: A (Inquiry);
Graduate Research Element	Waveform Analysis

Student Learning Goal:
Students will design an experiment to analyze the timbre of different instruments using various software tools.

Physics: 1. Apply inquiry-based and problem-solving processes and skills to scientific Investigations: (b) Clarify research questions and design laboratory investigations; (c) Demonstrate the use of scientific inquiry and methods to formulate, conduct, and evaluate laboratory investigations (e.g., hypotheses, experimental design, observations, data analyses, interpretations, theory development); (d) Organize data to construct graphs (e.g., plotting points, labeling x-and y-axis, creating appropriate titles and legends for circle, bar, and line graphs) draw conclusions and make inferences; (f) Formulate and revise scientific explanations and models using logic and evidence (data analysis).
4. Discuss the characteristics and properties of light and sound: (a) Describe and model the characteristics and properties of mechanical waves - Relationships among wave characteristics such as velocity, period, frequency, amplitude, phase, and wavelength; Standing waves and waves in specific media (e.g., stretched string, water surface, air, etc.)

National Science Education Standards of Content 9-12
A (Inquiry): Abilities Necessary to do Scientific Inquiry: Design and conduct scientific investigations – Designing and conducting scientific investigation requires introduction to the major concepts being investigated in the area, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with a critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations.

Materials Needed (supplies, hand-outs, resources): Various instruments (or premade recordings), microphone, a computer equipped with a microphone input, and audio analysis software - Many standard data logging programs, such as DataStudio and LoggerPro, include some analysis tools, i.e. Fast Fourier Transform. However, a plethora of free audio analysis programs are available with more sophisticated tools. See the Wikipedia page on list of free software for audio: http://en.wikipedia.org/wiki/List_of_free_software_for_audio

Lesson Performance Task/Assessment:
In this lesson, students will design an experiment to objectively characterize the quality of a particular sound, commonly referred to as its Timbre. Students will be introduced to common methods of measuring timbre, and they will be encouraged to devise their own method. Students will present their findings to the class and defend their method as an objective measure timbre.

Lesson Relevance to Performance Task and Students:
This lesson is heavily inquiry based. Students will start with a vague notion of a subjective experience and explore ways of objectively characterizing that experience through the acquisition of data. Such a process is characteristic of all scientific inquiry and is thus relevant to any student of science. This lesson also connects abstract properties of waves, such as spectrum and envelope, to the common experience of listening to music.

Anticipatory Set/Capture Interest:
The teacher will play a variety of recorded sound clips of various instruments and ask the students to identify the instrument that was recorded. The class will then discuss the properties they listened for in order to distinguish between the various instruments.

Guided Practice:
Day 1:
The teacher will give a brief introduction to current theories of sound quality (psychoacoustics) and demonstrate some of the tools that scientists use to characterize sound. The teacher should encourage students to use a combination of standard tools and their own ideas to evaluate the timbre of different sound sources.

Day 2:
The teacher will facilitate classroom presentations of the students' findings and moderate discussion.

Independent Practice:
Day 1:
Students will choose from a variety of instruments and recordings and apply standard audio analysis tools to characterize each sample's timbre. Students will then discuss with

their partner what aspects of sound quality they have evaluated and look for something that they think is missing. Students will then attempt to create a new method of analysis that characterizes the "missing quality" that they have identified.

Day 2:
Students will present the results of their investigation to the rest of the class.

Remediation and/or Enrichment:
R: individual IEP; partner help throughout lesson

E:

Check(s) for Understanding:
* What does the word Timbre mean?
* List several common measures of Timbre?
* What aspects of a sound can be characterized by its envelope? its spectrum?

Closure:
The teacher will lead a classroom discussion on the extent to which the quality of music may be determined objectively using the tools explored in this lab. The discussion might explore the possibility of programming a computer to distinguish between "music" and "noise".

Possible Alternate Subject Integrations:
* Math – The Fast Fourier Transform (FFT) is a numerical approximation of the Fourier Transform. The Fourier transform can be used to introduce students to many of the concepts of functional analysis in a context that can be directly related to experience.

Teacher Notes: