

Lesson Title: Guitar Design Challenge- Exploring How Music is Made

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Targeted Grade Level: middle & high School (7-12)

Time Needed: 3-4 (45-mins class periods)

Intro/Rationale:

Music is a universal language. Songs, music, and instruments contribute to the identity of a culture. Although students have the content knowledge of how sound is created, many do not understand how vibrations affect the pitch, tone, and resonance that contribute to the diverse combinations that make music enjoyable. The “Guitar Design Challenge” lesson can be introduced at the beginning of a wave unit or the end. The challenge could be done within three to four class periods, but may require additional time outside the classroom. After exploring the properties of a wave in the previous lessons, like the [Wave on a String simulation](#), students will explore the relationship of vibrations and other sound wave properties. Students then design their instrument, which they will present and play their guitar to the class. The problem in this challenge is that they must build the guitar using recycled materials. It must meet the given constraints—as listed in the student directions section. Since music is relatable to everyone, the lesson is appropriate and fits with culturally responsive pedagogy. It is a powerful tool to also understand the engineering process, as well as learning physical science principles.

Standards:

NGSS Performance Expectations

HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
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<ul style="list-style-type: none"> • <i>Asking Questions and Defining Problems</i> • <i>Developing and using models</i> • <i>Analyzing and Interpreting Data</i> • <i>Constructing explanations and designing solutions</i> • <i>Obtaining, Evaluating, and Communicating Information</i> 	<ul style="list-style-type: none"> • <i>PS3.A: Definitions of Energy</i> (Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. (MS-PS3-1)) • <i>PS4.A: Wave Properties</i> (Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.) • <i>PS3D: Energy in Chemical Processes and Everyday Life</i> (Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.) • <i>ETS1.A: Defining and Delimiting Engineering Problems</i> (The more precisely a design task’s criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)) • <i>ETS1.C: Optimizing the Design Solution</i> The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4) 	<ul style="list-style-type: none"> • <i>Cause and effect</i> • <i>Systems and system model</i> • <i>Energy and matter</i>
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Measurable Student Learning Objectives:

1. Students will be able to discuss the parts of a guitar and their functions.
2. Students will be able to collect data for string and resonating-cavity performance.
3. Students will be able to present their guitar and performance to the class.
4. Students will be able to journal their process in an engineering notebook.
5. Students will be able to construct their final report as a group with analysis, reflection, and summary.

Assessment:

There are both formative and summative assessments in the Guitar Design Lesson. In day one, each student, in a small group, will research the parts of a guitar, as well as its function. Students will sketch the parts and annotate it as a group. Then students list their findings on a collaborative board. Students should also write their introductory page in their engineering notebook. As part of their summative, students are assessed based on their group's final report and presentation about their guitar design to the class. In their final report, they will list the materials they used, include their sketches, explain their design building process, show pictures, make a summary analysis of the guitar components, and reflect on their experience. Finally, students will make a five-minute presentation summarizing their project to the rest of the class. As an extension, students would be able to a short song with their completed guitar. See [rubrics](#) for measuring assessments.

Student Directions

Day 1	Instructions for students- <ul style="list-style-type: none">• Students will first watch "Marcin Patrzalek: Polish Guitarist MURDERS His Guitar! WOW! America's Got Talent 2019"• Explore the various parts of a guitar and its functions.• Sketch the first design of your prototype making sure to annotate the parts.• Present your findings to the teacher as he or she is circulating.• Read the expectations, rubric, and criteria for your project.• Open your notebook, and write the introduction on page one.
Day 2	<ul style="list-style-type: none">• Listen and watch low to high notes and reflect on the two sets. "RHYTHM GUITAR: Upper & Lower Register Chords"• Turn and Talk: Describe the spacing of the frets on a guitar (or real one if available).

	<ul style="list-style-type: none">• Whole Group: Discuss the differences between the random eight notes and the octave notes• Watch the teacher demonstration to show how the Pano Tuner app works.• Refer to the handout “Setting Up Your Guitar to Play a Full Octave.”• Work on your instruments
Day 3	<ul style="list-style-type: none">• Continue to work on instruments and fill out your engineering notebook• Work on Report and Presentation
Day 4	<ul style="list-style-type: none">• Presentation• Final Thoughts and Reflections

Constraints*

- No parts or pieces can be from a real guitar.
- The guitar must be constructed out of recycled and re-purposed materials.
- The guitar must be clearly audible across the classroom.
- The guitar must be tunable
- The guitar must have frets marked so that a full octave can be played.
- The guitar must contain a resonating cavity.
- The guitar must be robust enough to be played multiple times.

*As stated in the student handout from “Beyond the Egg Drop” (2018).

Content

Science	Engineering
<ul style="list-style-type: none">• Wave model• Standing wave• Frequency• Tension• Resonance• Pitch• Vibrations• Sound• Understanding physics of each guitar component• Location of frets	<ul style="list-style-type: none">• Building and designing functioning physical model• Systems- Vibrations, Resonator• Reverse engineering

Materials and Equipment:

- Boxes (sizes will vary)
- Various string types (twin, kite string, fishing line, thread, yarn)
- Smartphone or Tablets with Pano tuning app ([Android](#) and [Apple](#))
- Engineering Notebooks
- Handouts for each student
- Smart board/Projector and Internet
- Safety Goggles
- (Optional) real guitars for groups to observe parts and explore
- (Optional) tuning forks
- (Optional) containers made from different materials (plastic, glass, cardboard, metal)

Lesson Adapted from:

Eisenkraft, A., & Freake, S. C. (2018). Engineering Infusion with Waves. In *Beyond the egg drop: Infusing engineering into high school physics* (pp. 303-320). Arlington, VA: NSTA Press, National Science Teachers Association.

Rubrics

Rubric for Engineering Design Notebook (Individual Grade)

Graded Element	Details	Points
Daily Log Format	<ul style="list-style-type: none"> Dates, group members in attendance, signature at end, neat layout 	_____ /10
Level of Detail	<ul style="list-style-type: none"> Detailed entries including notes/thoughts and reflections (can be seen on multiple occasions) 	_____ /15
Data and Analysis	<ul style="list-style-type: none"> Data collected in neat format so that it is easily understood, can be seen on multiple occasions Each time data is collected, claims are made (What can you tell from the data collected and what evidence do you have to show this?) Analysis of data included, summarized, and explained each time data is collected 	_____ /15
Sketches	<ul style="list-style-type: none"> Sketches are included throughout the process (multiple occasions) and are annotated/labeled Sketches include initial brainstorming ideas, along-the-way sketches, and final designs 	_____ /10
Notes	<ul style="list-style-type: none"> Meaningful notes are taken throughout the process Notes include personal reflections and thoughts about the process. Notes include what you completed and what you are planning on completing at the next group meeting. 	_____ /15

TOTAL _____ / 65

Rubric for Guitar Project Final Report

Element Graded	Base Points				Point Calculation	Total Points
	4	3	2	1		
Materials <ul style="list-style-type: none"> • Materials list includes all materials used AND all tools used. 					× 1 =	
Final design sketch <ul style="list-style-type: none"> • Detailed sketches (several if needed) including labels of parts/ materials used on the sketch • Dimensions are included on the sketch 					× 2 =	
Build process <ul style="list-style-type: none"> • Complete and thorough description of entire build process from beginning to end (can be step-by-step or paragraph form) 					× 2 =	
Pictures <ul style="list-style-type: none"> • A variety of pictures (easy to see) are included from the entire build process and pictures are annotated 					× 2 =	
Analysis <ul style="list-style-type: none"> • More than one analysis process is described, including what was done during the analysis, what was being tested, the results of the analysis, and how the results helped inform design decisions 					× 2 =	

Rubric for Completed Guitar and Presentation

Constraint Details	4	3	2	1	0
Completed guitar met all constraints ____ / 12 (add at bottom)					
Use of recycled materials but not real guitar parts <ul style="list-style-type: none"> No part of the guitar is from an actual guitar. You successfully and creatively used recycled and repurposed materials in creating the guitar. 					
Strings and frets <ul style="list-style-type: none"> Frets are marked on the neck in the correct locations for playing an octave. String choice gives the guitar a nice sound. 					
Resonating cavity <ul style="list-style-type: none"> Resonating cavity is designed to give nice resonance, making guitar easily heard. 					
Playability of guitar <ul style="list-style-type: none"> Guitar is easily played. Playability was clearly taken into account when designing the guitar. Strings have an easy way to tune them. 					
Sound of guitar <ul style="list-style-type: none"> Guitar is easily heard across the classroom, even when noisy. Guitar has a pleasant sound 					
Song played <ul style="list-style-type: none"> Choice is creative. Song is recognizable. Song uses most of the notes of the octave. 					
Octave played <ul style="list-style-type: none"> Octave is correct and easily played. 					

Points for constraint details: _____

Points from above for meeting constraints: _____

TOTAL SCORE _____ / 40

Rubric for Guitar Project Final Report (continued)

Element Graded	Base Points				Point Calculation	Total Points
	4	3	2	1		
Reflection <ul style="list-style-type: none"> Detailed discussion of how and why your final completed guitar differed from your original brainstormed design. Difficulties your group encountered in the design and build process and how the group was able to overcome those difficulties. 					x2 =	
Changes <ul style="list-style-type: none"> Detailed discussion of several changes your group would make if you had to build another guitar or to redo this project Reasoning provided for why your group would want to make those specific changes. 					x2 =	

REPORT TOTAL _____ / 52