What a Wavy World!

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for the STEM Education Center at WPI's Summer 2022 Research Experience for Teachers program

Subject: Physics
Grade Level: 9-12
United Nations Sustainable Development Goal 9 & 4:
The funding of research on this topic directly connects with Goal 9 for the United Nations Sustainable Development Goals "Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation." This lesson will touch on SDG 9, but it will more target SDG 4 (quality education), and its target, "By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship."

Overview

There is so much technology in the world which works in ways that we completely take for granted. It's great that we have engineers who come up with ideas, but there is a wealth of creativity that is untapped in people who have no STEM background. We need to create good quality, relatable, and accessible educational material to inform others so that misinformation does not spread, to foster more interest in science and engineering, and possibly generate new and better ideas for the future.

Basic steps:

1. Review waves and wave superposition
2. Research a wave technology that your family is suspicious of, or that you are familiar with, or that you are just interested in (driverless cars, blue light sunglasses, wifi, night-vision goggles, noise-canceling earbuds, microwaves, MRI's, etc.)
3. Create a visual (brochure, video, story, pop-up) to explain this technology to your grandparents, siblings, parents, or guardians. Choose the media based on your audience. Extra points awarded for a voice recording or video of you presenting to your target audience.

Essential Question:
How does [insert technology] reflect the physics understanding of wave properties that the engineer who designed it had? How does this technology use the properties of waves (whether acoustic or electromagnetic) to its advantage?

Standards & Learning Targets

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*
Clarification Statements:

- Emphasis is on qualitative information and descriptions.
- Examples of technological devices could include solar cells capturing light and converting it to electricity, medical imaging, and communications technology.

- Examples of principles of wave behavior and wave interactions with matter include resonance, photoelectric effect, refraction, and constructive and destructive interference.

State Assessment Boundary:

- Band theory is not expected in state assessment.

Vocabulary	**Tier 1**	**Tier 2**	**Tier 3**
	communicate information behavior interactions capture	technological devices principles matter energy convert transmit	wave behavior wave interactions solar cells medical imaging resonance photoelectric effect refraction constructive and destructive interference

What do students need to **KNOW**?	1. Students will know how to use the following vocabulary words in context: constructive and destructive interference, reflection, intensity, frequency, communicate, transmit, and receive. 2. Students will extend their knowledge from ocean waves to mechanical waves to electromagnetic waves by using similar vocabulary to describe each of them, as well as identifying their differences 3. Students will know the parts of a wave and the different factors that affect mechanical and electromagnetic waves 4. Students will achieve an understanding of how different technologies use the properties of waves to gather information
What do students need to **DO**?	1. Students will calculate the superposition waveform of two incoming waves 2. Students will communicate technical information about how information is transmitted and captured through waves 3. Students will explain through a creative visual how a specific technology utilizes the properties of waves to its advantage
What will students **CREATE**?	1. A graph of two waves' superposition waveform 2. A unique visual for their chosen wave technology

SEP8. Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Being a critical consumer of information about science and engineering requires the ability to read or view reports of scientific or technological advances or applications (whether found in the press, on the Internet, or at a town meeting) and to recognize the salient ideas, identify sources of error and methodological flaws, distinguish observations from inferences, arguments from explanations, and claims from evidence. Scientists and engineers use multiple sources of information to evaluate the merit and validity of claims, methods, and designs. Communicating information, evidence, and ideas can be done in multiple ways: using tables, diagrams, graphs, models, interactive displays, and equations, as well as orally and in writing.

Vocabulary	Tier 1	Tier 2	Tier 3
	Communicate Ideas Reports Scientific Applications arguments	Methods Critique Flaws Observations Claims Evidence validity	Salient Methodological Inferences
What do students need to **KNOW**?	1. Students will know good research practices, including using credible sources and how to skim text. 2. Students will know how to listen carefully to their peers in order to give constructive feedback		
What do students need to **DO**?	1. Students will apply good practices as they research their wave technology 2. Students will communicate clearly and persuasively the ideas and methods they generate. 3. Students will recognize the salient ideas from the texts or other sources they are using 4. Students will identify sources of error and methodological flaws in their own designs		
What will students **CREATE**?	1. A list of possible visuals they can use, such as tables, diagrams, graphs, models, interactive displays, and equations. 2. Peer feedback form		

ELA Standard:
WCA.11-12.2: Write informative/explanatory texts (e.g., essays, oral reports, biographical feature articles) to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.

Vocabulary	Tier 1	Tier 2	Tier 3
	Write Ideas Selection Organization Contect	Informative Essays Articles Examine Convey Analysis	Explanatory Biographical
What do students need to **KNOW**?	1. Students will know the audience they are trying to convey information to 2. Students will distinguish between what is important and unimportant for explaining their chosen technology to their specified audience		
What do students need to **DO**?	1. Students will make informed decisions about the analogies and graphics of their visual based on their audience 2. Students will write informative/explanatory texts (e.g., essays, oral reports, biographical feature articles) as a part of their visual 3. Students will convey complex ideas, concepts, and information clearly		

	and accurately, and at a level appropriate to their audience
What will students **CREATE**?	*See above*

Prior Knowledge

Wave vocabulary and basic concepts

Materials/Resources

- Lesson Slides
- Student Instructions
- Peer Feedback Form
- Waves HW sheet
- Rope
- Slinky
- Chromebooks
- Graph paper
- Vernier ultrasonic sensor (optional, for demonstration)
- Craft materials
- Poster paper
- Presentation boards
- Markers

Timeline of Activities

Duration	Activity	Instructions	Product
25 min	Review what waves are	• Ocean waves analogy, probe students knowledge • Quick review of what waves are • Use rope to show parts of a wave • Brief homework on waves using Phet	Waves Phet simulation homework
50 min	Superposition activity	• Extra credit given to the student who can think of an application of wave superposition • Given two pieces of graph paper, draw axes and label out 25 squares • Draw a random waveform on both • Pass one of them to a partner	Two random waveforms The superposition waveform calculated using at least 20 points

		• Calculate the superposition of remaining wave and peer's wave using 20 points • Turn in superposition waveform	
25 min	Review how to do research and introduce the project	• Teacher demonstration of how to research something • Introduction of the project, give essential question • Students should decide on a technology important to them or their family	Student verbal decision of technology to study
10 min	Class brainstorming about tech	• Engage students with cymatics video • Students engage in a class discussion about technologies they could research, including technologies that they don't know how it works	Student verbal decision of technology to study
30 min	Begin research	• Students have time to go to the library or use their chromebooks to research their chosen technology • Teacher circles and checks in	Verbal check in
20 min	Pop share with class, option to change technology	• Share research so far, ~30 second pitch • Students given the option to switch what they are researching, also to discuss with people researching the same thing • Ask if any students have figured out why superposition of waves is a useful concept	~30 second pitch of what students have found out with their research so far
40 min	Finish research and begin informative visual	• Students continue their research and begin working individually on their visuals	None
5 min	Shark tank with teacher (during research)	• As students are working, teacher will come around and pull students aside and check in on their progress, as well as offer support • Practice presentation	Teacher notes on research progress physics understanding
15 min	Peer feedback	• Students find a partner and share their incomplete visuals. Peers provide feedback about what is good and what could be improved	Peer-feedback must be documented and turned in with final project

45 min	Finish visual	• Students given time to complete the visual in class	Completed informational visual catered towards a certain audience
15 min	Showcase walkthrough	• Students vote on most creative visual, most informative visual, and visual best suited for audience • Bingo card?	Completed walkthrough sheet, including compare and contrast section and voting
n/a	Extra credit: bring back video or voice recording of presentation	• At home, minimum of 2 minutes	

Culturally Responsive Teaching Strategies

Give students options	In this lesson, students have options about which technology they'd like to research. This is to increase engagement, because if students are learning about something that interests them, they will more likely participate. Not only that, but there is a check in where students can even change their mind about what they'd like to research. This is good for students, and it helps to develop depth. When students share with each other it also develops breadth in the content.
Have students personalize their projects to their community	This strategy hits the ELA and the practice standards for writing informative/explanatory texts and obtaining, evaluating, and communicating information. Students have to know their audience and write explanations catered to that audience. It also helps put students in a comfort zone where they know that the presentation is with someone they know well.
Have students receive lots of feedback, both from peers and teacher	This is a well-known strategy which fits into any project. Feedback is very important for improving the end product, which in this case is the visual. It also is a good way to scaffold the project so that students don't feel overwhelmed.

Career Connections

This project connects well to STEM careers, because it's all about how we as humans have tried to solve problems with what we know. This is the job of an engineer. Going even farther back, it

also teaches students about identifying things in nature that we can use to our advantage, which is the role of the scientist.

With the skills learned in this project, students also learn about marketing since they need to keep in mind their target audience.

We could try to bring in a representative from Bose or Sony or another earbud producer to explain how the physics of wave superposition is used in their earbuds, and the engineering challenges/limitations of this technology.

Assessment(s)

1. Wave superposition graph using at least 20 points for the calculation
2. Brochure for wave technology (rubric)