

GLASSY MUSIC

STUDENTS INVESTIGATE MUSICAL SOUNDS AND PITCH DEPENDENCE

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Musical glasses, Baltimore (United States), about 1830.

Exposition in the National Museum of Arts, Boston, USA

SUITABLE FOR AGE(S)

12 - 18 years

SUBJECT(S)

Physics

KEY FOCUS

Brainstorming
Developing hypothesis

INTRODUCTION

This task introduces students to inquiry-based learning (IBL) at two sublevels of guided inquiry, focusing on the topic of sound and musical instruments.

The lesson bridges science, physics, and music, involving hypothesising, planning, and conducting a practical experimental activity (with a focus on controlling variables) and reporting. Students experience different aspects of playing and calibrating non-standard instruments, such as spoons, bottles, and glasses, to understand the properties of sound, including pitch, frequency, and resonance. Measurements are taken using ICT tools, i.e., apps like Spectroid and Phyphox.

By promoting collaborative work, group discussion, and hands-on exploration, the task can be used in introductory lessons during the first year of school when new classes are formed and students are not yet familiar with one another.

TASK DESCRIPTION

The task comprises several phases that progressively introduce students to scientific inquiry in the context of sound:

1. Brainstorming Session (10–15 min): Elicits students' prior knowledge about sound, its production, and propagation in different media.
2. ICT Tool Installation and Testing (10 min): Students install and evaluate apps (e.g., Spectroid, Phyphox) to record and analyze sound frequencies.
3. Guided Inquiry – Bottles (25 min): Students investigate how the height of the air column in a bottle affects sound frequency.
4. Guided Inquiry – Musical Glasses (45 min): Students explore how various parameters (e.g., water level, glass shape) influence sound frequency.
5. Closing by the Teacher (5 min): Teacher wraps up the session and connects it to future learning topics.

Each phase encourages hypothesis formulation, planning, experimentation, data collection and visualization, and scientific communication.

TASK PREPARATION

To prepare for the task, the teacher should

- prepare facilitation strategies for group discussions,
- develop a flexible storyline or historical context (e.g., Native American use of physics) to spark interest and anchor the activity in a real-world context, and
- select appropriate ICT tools (apps like Spectroid and Phyphox) and test them beforehand

Materials needed:

- Spoons (preferably metal)
- Empty glass bottles (identical or varied for comparison)
- Wine glasses (one per group)
- Water containers
- Rulers or measuring cylinders
- Smartphones with installed apps:
 - Spectroid (for spectrum analysis)
 - Phyphox (for sound frequency and waveform analysis)
- Paper towels or cloths (for drying glasses)
- Worksheets for data collection and graphing
- Projector or whiteboard (for student presentations)

TASK IMPLEMENTATION

Brainstorming (10-15 min)

The brainstorming session aims to introduce learners to the topic by leveraging their everyday knowledge and prior knowledge from physics or music classes.

A storyline can be composed around how the Native Americans used physics and chemistry. Or any other story involving learners benefiting from their prior knowledge and experience.

The purpose is to learn that:

- sounds are produced as a mechanical wave in a particular medium
- sounds can propagate in solids, liquids, and gases
- sound dumping is different in different mediums
- people used different instruments in the history of human beings
- sound is characterised by frequency

Mini-Experiment: “Spoon Bell” - At the end of the brainstorming, a short experiment through observation is proposed by listening to the sounds produced by a spoon on tapping surfaces of different materials

ICT tool – installation and testing (10 min)

To collect measurements of sound frequency, students are asked to install and test any app on their smartphones, enabling the recording of sound frequency. Each student does it individually, but students discuss different apps' effectiveness and accuracy in groups.

Guided Inquiry – Bottles (25 min)

1. Each student is given an empty glass bottle.
2. Teacher asks students to play a sound on an empty glass bottle. Students compare the sounds of different bottles (frequency, volume)
3. Teacher poses a question: How does the sound frequency depend on the air column's height over the water surface?
4. In groups of four, students
 - Discuss and put forward a hypothesis.
 - Plan the investigation.
 - Collect materials.
 - Conduct the experiment.
 - Collect and visualise data on the graph.
 - Draw conclusions.
 - Present their group findings to the class (lasts 5 min).

Guided Inquiry – Musical glasses (45 min)

1. Each group is given an empty wine glass.
2. Teacher asks students to play a sound on an empty glass border. Students discuss how to do that.
3. Teacher poses a question: Investigate the dependence of the sound frequency on a selected parameter
4. Students in groups of four:
 - select an independent variable
 - discuss and put forward a hypothesis
 - plan the investigation
 - collect materials
 - conduct the experiment
 - collect and visualise data on the graph
 - draw conclusions
 - present their group findings to the class (last 5-10 min)

Closing by teacher (5 min)

The teacher summarises key concepts and highlights skills developed: scientific inquiry, teamwork, ICT use, and connect findings to upcoming lessons for the next topic/class.

CONCLUSION

This guided inquiry task effectively introduces students to IBL principles while covering fundamental physics concepts related to sound. By engaging students in hands-on experiments with simple, familiar materials and incorporating mobile ICT tools, the activity fostered both curiosity and scientific thinking. It also served as a valuable team-building experience in newly formed classes, enhancing group dynamics. The structure enables flexibility in adapting to various educational contexts and provides a strong foundation for further inquiry-based units.

APPENDIX

The context and additional information

Sound is a longitudinal wave phenomenon. When the sound propagates through the air (or any other matter), the molecules oscillate around the initial position along the direction of the propagation (and back) – hence the name longitudinal waves. Areas of compressed matter (with slightly heightened pressure) are formed, with areas of lower density (and pressure) in between, propagating through the air. The sound waves propagate through the air with a speed of $v = 343$ m/s (at 20 °C).

Sound from the singing tubes is produced by oscillations of the air column trapped in the tube. Oscillations propagate along the air column, forming waves which get reflected at the end of the tube (even if it is open) and propagate in the opposite direction. Waves travelling in opposite directions combine, sometimes forming standing waves that lead to a phenomenon called acoustic resonance (Halliday et al., 2014).

The pitch of the sound produced by hollow tubes depends on the length and shape of the tubes, as well as whether their ends are closed or open, and is similar to that of many musical instruments, such as flutes and organs.

Cylindrical tubes of length L with both ends opened resonate at frequencies f , approximately given by

$$f = \frac{nv}{2L}$$

Where n is a positive integer (1, 2, 3 ... - resonance node) and v is the speed of the sound. In this approximation, only the length of the tube affects its pitch. More accurate description, however, considers that the pitch is also affected by the tube diameter, because at the open end, the waves are not reflected exactly at the end of the tube. Frequency f is hence given by

$$f = \frac{nv}{2(L + 0,6d)}$$

Where d is the diameter of the tube (Wiki).

Worksheet: Singing tubes

Safety note: Do not blow into the tubes!

1. You have a set of different tubes at your disposal. Observe and compare them.
 - Write down the variables on the set of given tubes (properties by which the tubes differ).
 - Also write down the constants (properties according to which the tubes are the same).
 - If you tap the tubes on your palm, they make a sound. Try it. Compare the sounds of different tubes. Are they the same or different?

2. Make a hypothesis: Which characteristic of the tube determines the pitch of the sound emitted by the tube?

3. Test your hypothesis. Is your opinion correct? Find out with an inquiry. *My inquiry question is:___*

4. Make an inquiry plan to test your hypothesis with experiments.
 - Choose and write down the independent variable (what you will change during the inquiry):
 - Choose and write down the dependent variable (what you will observe, monitor, measure...):
 - List the constants (What will you not change between experiments to make the research fair?):
 - Choose a pair of tubes to test your hypothesis. Write down which two tubes you chose to try. Explain why you chose this pair of tubes.

5. Describe the experiment and interpret the results! What are your findings (answer to the inquiry question)?