

THE GREAT SOUND ESCAPE

Investigating the Sound of Silence

thematic: environment, well-being and public health



Introduction

In our increasingly urbanized world, managing noise pollution has become critical for creating sustainable, livable cities. Continuous exposure to urban noise affects both immediate well-being and daily productivity while contributing to long-term health issue (chronic stress, sleep disturbances, cardiovascular complications, and cognitive impairments). This activity explores how different materials reduce sound waves' strength through attenuation, providing valuable insights into architectural and design choices that enhance comfort in residential, educational, and public spaces.

The principles of noise reduction through materials offer practical solutions to urban challenges. When integrated into urban planning, these principles create environmentally conscious and inclusive cities that prioritize residents' health. Sound attenuation strategies in urban design help create spaces that support both physical and mental health while fostering sustainable community development.

By mitigating noise pollution in residential and public spaces and reducing industrial activities' impact on neighboring communities, sound attenuation creates healthier urban environments. This approach develops harmonious spaces where people can live, work, and thrive without excessive noise exposure's adverse effects.

This activity aligns with several **United Nations Sustainable Development Goals (SDGs)**. It supports **SDG 3: Good Health and Well-Being** by addressing noise pollution as an environmental health risk. Through soundproofing strategies in urban planning, it contributes to **SDG 11: Sustainable Cities and Communities**. The activity also aligns with **SDG 12: Responsible Consumption and Production** by evaluating soundproofing materials' lifecycle implications and promoting sustainable construction choices.

Students will act as scientists to measure sound attenuation and explore noise pollution reduction while studying sound propagation and reflection. This inquiry-based approach helps them understand noise and sound fundamentals while connecting their learning to global sustainability challenges. The activity develops critical thinking and problem-solving skills essential for building a sustainable future.

Through this activity, students will develop a scientific mindset while addressing a critical urban issue: reducing noise pollution to improve the quality of life in cities.

Interdisciplinarity



physics

engineering

Sustainable Development Goals

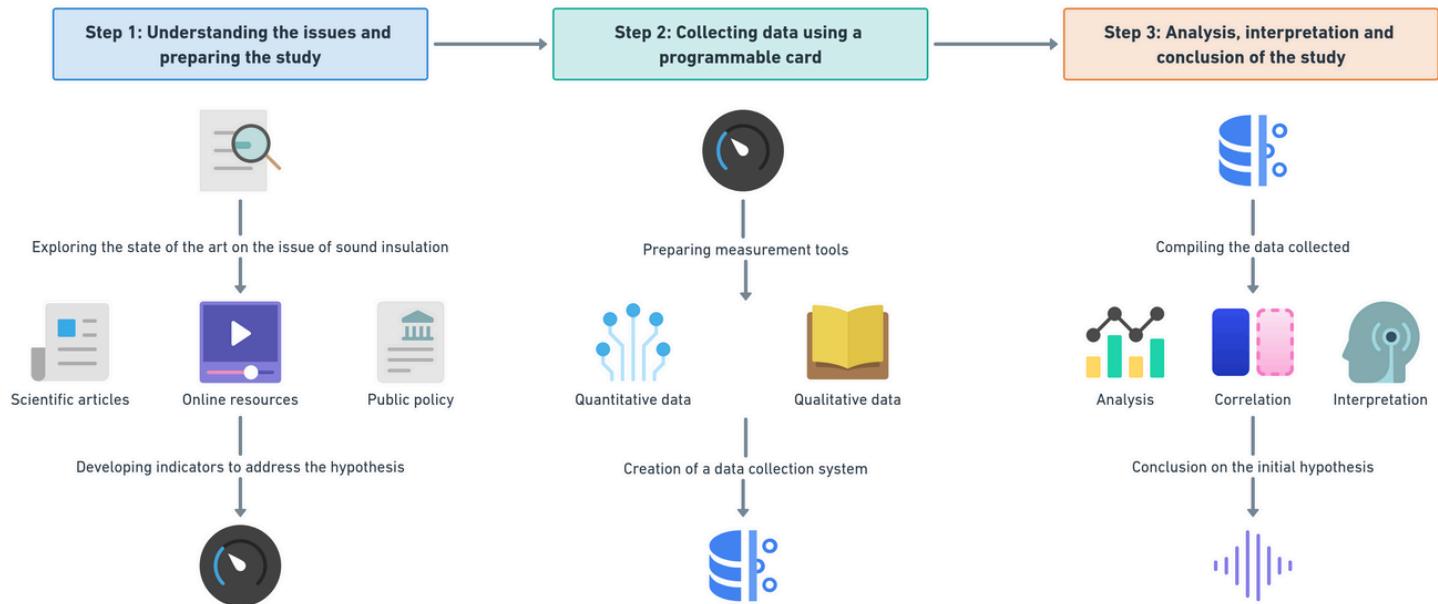




Overview

Protocol Structure

The experimentation consists of three key steps, guiding students through the scientific process from exploring foundational concepts to analyzing and interpreting experimental data. Below is the outline of the course:



Exploring Key Concepts, Formulating the Research Question, and Conducting Background Research

Students begin by exploring the fundamental principles of sound and noise, including sound waves, the decibel scale, and the impacts of noise pollution on health and well-being. They will discuss and formulate a research question, such as determining the most effective materials for sound insulation or investigating how thickness or density affects sound attenuation. This phase includes a literature review, where students consult existing resources on soundproofing materials and their properties. This step fosters critical thinking, collaboration, and grounding their inquiry in scientific knowledge.

Designing and Conducting the Experiment

In this step, students will work collaboratively to design and execute an experimental protocol that allows them to measure the sound attenuation properties of different materials. Using a programmable microcontroller equipped with a microphone and sound source, they will measure sound intensity before and after it passes through selected materials. Students will document the experimental conditions, such as material type, thickness, and density, ensuring the setup is consistent and repeatable. This phase emphasizes hands-on learning and scientific rigor while collecting quantitative data to test their hypotheses.

Analyzing Data and Reflecting on Results

Back in the classroom, students will analyze the collected data to identify patterns and relationships between material properties and sound attenuation. They will use visual tools such as graphs and charts to represent their findings and calculate relevant metrics like decibel reductions. This phase also includes a reflection on the experimental process, where students evaluate potential sources of error, limitations in the setup, and ways to improve the methodology. Additionally, they will link their findings to real-world applications, such as urban noise reduction and sustainable building practices. This step strengthens critical thinking, data interpretation, and communication skills.

It is common to talk about insulation in the context of energy conservation. For example, to make our homes less energy-consuming or to keep our water bottle cool on hot summer days. It is also possible to soundproof, to reduce the intensity of outside noise. How do we measure "noise" or its attenuation? Does the shape of the insulating material have an impact? What are the insulating materials? This activity aims to try different materials (wood, metal,

foam, ...) and determine which one is the most insulating, but also to understand the measurement of noise and the "decibel" scale.

This protocol describes a scientific experiment aimed at measuring the sound insulation power of different materials. Data collection is done using a microphone to measure the sound intensity inside and outside boxes containing different materials. The experiment also allows understanding how to connect the electronic board to other peripherals and retrieve data for later analysis.

Getting started

Duration: The activity will span three lessons. The first lesson focuses on exploring key concepts, conducting a literature review, and formulating a research question. The second lesson is dedicated to designing and performing the experiment, including data collection. The third lesson will involve analyzing the results, drawing conclusions, and reflecting on the experiment's methodology and findings.

Level of difficulty: *The activity combines theoretical exploration (understanding sound and noise, formulating hypotheses) with practical application (setting up the experiment, collecting data) and analytical thinking (interpreting and visualizing results).*



Material needed:

- 1 programmable microcontroller (e.g., STM32 IoT Node or micro:bit board)
- 1 microphone (e.g., MP34DT01)
- 1 buzzer (for sound generation)
- 1 LCD screen (for data display)
- Connection cables and a USB cable (micro B)
- Sample materials to test (e.g., foam, wood, metal, fabric)
- Notebook or digital tools for recording and analyzing data

Glossary

Keywords & Concepts	Definitions
Acoustic Attenuation	The reduction in the strength or intensity of sound as it travels through a medium or encounters a barrier.
Amplitude	The height of a sound wave, determining the loudness of the sound. Larger amplitudes correspond to louder sounds.
Decibel (dB)	A logarithmic unit used to measure sound intensity. A 10 dB decrease corresponds to a tenfold reduction in sound power.
Density	The mass of a material per unit volume, typically measured in grams per cubic centimeter (g/cm^3). Denser materials often reflect sound more.
Frequency	The number of cycles a sound wave completes in one second, measured in hertz (Hz). Determines the pitch of the sound.
Microcontroller	A programmable electronic device used to process sound intensity data from a microphone and display the results.
Noise Pollution	Harmful or unwanted sound that disrupts the environment or negatively affects human and animal health.
Porous Material	A material containing small, interconnected voids that trap and dissipate sound energy, making it effective at absorbing sound.
Propagation	The movement or transmission of sound waves through a medium, such as air, water, or solid materials.
Reflection (of Sound)	The bouncing back of sound waves when they encounter a barrier. Reflective materials, like metal, tend to redirect sound rather than absorb it.
Refraction (of Sound)	The bending of sound waves as they pass through materials of differing densities, changing the wave's speed and direction.
Resonance	A phenomenon where sound waves amplify as they match the natural frequency of a material or system, increasing sound intensity.
Sound Intensity	The power of a sound wave per unit area, typically measured in decibels (dB). It quantifies the loudness of sound.
Sound Wave	A vibration that travels through a medium as a wave of pressure. Sound waves vary in amplitude, frequency, and wavelength.
Soundproofing	The process of reducing or eliminating sound transmission between spaces, often using materials that absorb, block, or reflect sound.
Thickness (Material)	A measure of how wide or deep a material is. Increased thickness often improves a material's ability to attenuate sound.
Transmission (of Sound)	The passage of sound waves through a material. High transmission rates allow more sound to pass through, resulting in less attenuation.
Vibration	A repetitive back-and-forth motion of particles in a medium that produces sound waves.
Wavelength	The distance between two consecutive peaks or troughs of a sound wave. Wavelength is inversely proportional to frequency.



Protocol

Step 1 - Exploring Key Concepts, Formulating the Research Question, Conducting Background Research

Background and description of the problem to be solved in this step: In this step, students will explore the basic principles of sound and noise. They will learn about sound waves, intensity, and frequency, as well as the effects of noise pollution on health and productivity. Students will also reflect on real-world examples, such as urban noise and its mitigation in residential and public spaces.



Learning Objectives:

- **Core Competencies:** Understanding the physics of sound, noise measurement, and the environmental impact of noise pollution. Developing the ability to formulate hypotheses and connect theory with real-world challenges.
- **Auxiliary Competencies:** Conducting bibliographic research, critical thinking, and using scientific reasoning to define testable hypotheses.

Conceptualisation

Students will begin by defining key concepts such as sound intensity, attenuation, and the decibel scale. Teachers will guide them in understanding these ideas through interactive discussions and demonstrations, such as visualizing sound waves or comparing noise levels with a smartphone decibel meter. Next, the students will work on generating a specific research question. A research question is a clear, focused question that guides the investigation by identifying what the study aims to discover. It is important to formulate a research question before proposing a hypothesis because it sets the direction for the entire study and ensures that hypotheses are relevant and targeted. Formulating a well-defined research question is a critical step in scientific inquiry. A good research question acts as the foundation of the investigation, guiding all subsequent steps, from the design of the experiment to the interpretation of results. It ensures that the investigation remains focused and aligns with measurable and observable outcomes. A strong research question should be:

1. **clear and focused:** It should be specific enough to guide the investigation without being overly broad or ambiguous.
2. **testable:** It must involve variables that can be measured or observed.
3. **related to the key concept:** In this case, the question should directly address sound attenuation or properties of materials.
4. **Encourage investigation and analysis:** It should require the collection and evaluation of data to reach a conclusion.

Examples of effective research questions for this activity include:

- "Which materials are most effective at reducing sound intensity?"
- "How does the thickness of a material influence its ability to attenuate sound?"
- "Does a material's density correlate with its soundproofing capabilities?"

Once a research question is established, students will collaborate in small groups to brainstorm and explore factors that define sound and noise using books, scientific articles, and online resources. Based on their research, they will formulate hypotheses. An hypothesis is a statement that needs to be verified through experimentation (or calculation in fields like mathematics). The goal of an hypothesis is to provide potential answers to the research question. Validating or invalidating a hypothesis can lead to reformulating the research question to either refine or modify it. Even if the question is not fully answered, all hypotheses should help to better frame the potential answer and clarify its limitations. To help students craft a hypothesis, teachers can use the following structure:

- **Identify the independent variable (IV):** The factor that will be manipulated during the experiment (e.g., the type, thickness, or density of the material).
- **Identify the dependent variable (DV):** The factor that will be measured as a result of the manipulation (e.g., sound intensity or decibel reduction).
- **Connect the IV to the DV with a logical prediction:** Use prior knowledge or the results of the literature review to make an informed prediction about how the independent variable will influence the dependent variable.

Examples of Hypotheses

- For the research question "*Which materials are most effective at reducing sound intensity?*": **Hypothesis:** "Foam will attenuate sound more effectively than wood or metal due to its porous structure, which absorbs sound waves."
- For the research question "*How does the thickness of a material influence its ability to attenuate sound?*": **Hypothesis:** "Increasing the thickness of a material will result in greater sound attenuation, as thicker materials provide more barriers for sound waves to penetrate."
- For the research question "*Does a material's density correlate with its soundproofing capabilities?*": **Hypothesis:** "Denser materials, such as steel, will attenuate sound more effectively than less dense materials, as denser structures reflect more sound waves."

Guiding students in formulating hypotheses: Teachers can use prompts and discussions to help students think critically and connect their research question to a testable hypothesis:

1. **Prompt for prior knowledge:** What do you already know about how materials interact with sound?
2. **Encourage logical reasoning:** Based on your research, what characteristics of a material might affect its ability to reduce sound?
3. **Focus on measurability:** Can you measure or observe the effect of this characteristic (e.g., thickness or density) on sound attenuation?
4. **Support refinement:** If the hypothesis is too broad or untestable, ask students to narrow their focus or rephrase it to align with the available experimental setup.

Examples of guiding questions for students

- What properties of a material (e.g., texture, density, thickness) might influence its ability to block or absorb sound?
- How can we measure the reduction of sound intensity?
- Can we test this hypothesis using available tools and methods?
- What outcomes would support or refute the hypothesis?

How does a hypothesis shape the experimental design? A strong hypothesis provides a clear direction for the experiment by identifying what will be tested and measured. For example:

- If the hypothesis predicts that foam will outperform wood and metal in sound attenuation, the experimental design must compare sound intensity with and without these materials under controlled conditions.
- If the hypothesis involves thickness, the experiment must include materials of varying thicknesses while keeping other variables constant.

By ensuring that the hypothesis is directly linked to the research question and is testable, teachers can guide students to design experiments that yield meaningful and interpretable results.

Students Investigation

This phase bridges the gap between theoretical understanding and experimental design. Students will explore the properties of sound and its interaction with materials while constructing a rigorous protocol to test their hypothesis.

Preliminary Documentary Research: Students begin by investigating the nature of sound and the concept of attenuation. Sound, as a mechanical wave, propagates through a medium such as air, liquids, or solids. Its characteristics—intensity, frequency, and propagation—determine how it interacts with materials. For example, sound intensity, measured in decibels (dB), quantifies loudness on a logarithmic scale, where each 10 dB reduction

represents a tenfold decrease in intensity. The investigation begins with a study of sound as a physical phenomenon. Sound is a mechanical wave that propagates through a medium—such as air, liquids, or solids—via the vibration of particles. It is important to understand three key characteristics of sound:

1. **Frequency:** This is the number of wave cycles per second, measured in hertz (Hz). High-frequency sounds, such as a whistle, have short wavelengths, while low-frequency sounds, like a drumbeat, have long wavelengths. The frequency of a sound affects how materials interact with it, as some materials absorb high frequencies better than low ones.
2. **Amplitude and Intensity:** The amplitude of a sound wave determines its loudness, and its intensity, measured in decibels (dB), quantifies the power of the sound. The decibel scale is logarithmic, meaning a reduction of 10 dB corresponds to a tenfold decrease in intensity. Understanding this scale is critical for analyzing sound attenuation.
3. **Propagation:** Sound waves travel in three-dimensional space, and their behavior changes depending on the medium. When sound encounters a material, it can be reflected, absorbed, or transmitted. For example, foam absorbs sound energy and converts it into heat, while dense materials like metal reflect sound waves.

Through their research, students will investigate how these principles relate to soundproofing. They will explore the real-world implications of sound attenuation, such as its role in reducing noise pollution or improving building acoustics. Summarizing their findings in a collaborative report will help students solidify their theoretical understanding. To deepen their understanding, students will examine how materials either absorb, reflect, or diffuse sound. Porous materials like foam are known to absorb sound effectively, converting wave energy into heat, while denser materials such as metal primarily reflect sound.

A brief review of real-world applications, such as noise barriers or acoustic panels, will help students relate these concepts to practical scenarios. This research will conclude in a collaborative discussion where students summarize their findings, identify key factors influencing sound attenuation, and refine their understanding of variables such as material thickness and density.

Key Areas of Focus

Nature of Sound: Sound is a mechanical wave that propagates through a medium (air, liquids, solids) as vibrations of particles. **Key parameters to explore:**

- **Intensity (Amplitude):** Determines the loudness of sound and is measured in decibels (dB).
- **Frequency:** Indicates the pitch of the sound and is measured in hertz (Hz). Higher frequencies (e.g., treble) and lower frequencies (e.g., bass) may interact differently with materials.
- **Propagation:** Explains how sound waves spread out or are absorbed, reflected, or refracted when they encounter a material.



Sound Attenuation: The reduction of sound intensity as it travels through a material. Sound can be absorbed (converted to heat), reflected (bounced back), or diffused (spread in different directions). Materials such as foam absorb sound well due to their porous structure, while dense materials like metal reflect sound more effectively.

Measurement of Sound - Decibels (dB): A logarithmic unit used to express sound intensity. A reduction of 10 dB represents a tenfold decrease in intensity. Tools for measuring sound, such as microphones and programmable sensors, provide data that can quantify attenuation.

Developing the Experimental Protocol: Students then transition to designing an experiment that tests their hypothesis. Using programmable tools, such as a microcontroller with a microphone and buzzer, they will measure sound intensity before and after it passes through various materials. This setup allows for the systematic evaluation of sound attenuation.

The protocol must clearly define the study objective, variables, and methodology. The independent variable could be the type or thickness of the material, while the dependent variable is the measured reduction in sound intensity. Control variables, such as the sound source and microphone placement, ensure consistency across trials. Data

collection will involve recording sound intensity levels on both sides of the material and calculating attenuation as the difference in decibels. Students will carefully plan for repeatability, conducting multiple trials to ensure reliable results. They will also preemptively address challenges, such as external noise interference, and propose strategies to mitigate these issues.



To help you program the appropriate sensor, refer to the section “**Practical implementation 1 - Measuring the Intensity of Sound**”.

Documenting and Collaborating: Working in small groups, students will document their protocol with clear steps and justifications for their choices. Teachers will guide discussions to ensure the experimental design is feasible and scientifically rigorous. Through peer review, students will refine their approach and address gaps in their methodology. This collaboration not only strengthens the protocol but also fosters critical thinking and teamwork.

Preparing for Experimentation: Finally, students will conduct a dry run of their setup, testing the equipment and making adjustments as needed. This preparation ensures the experimental phase proceeds smoothly and aligns with their hypothesis. The protocol will serve as a roadmap for hands-on investigation and for meaningful data collection and analysis in the next step.

What are the expected results of this phase? By the end of this phase, students will have a well-developed experimental protocol informed by their research and hypothesis. They will understand the principles of sound attenuation and be ready to conduct their investigation with a clear plan in place.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** By completing this phase, students have provided essential elements for addressing their hypotheses. Through a combination of theoretical exploration and preliminary research, they have identified how sound interacts with materials and clarified the factors influencing sound attenuation. They now understand key concepts, such as the role of material properties (e.g., density, thickness, porosity) in absorbing, reflecting, or transmitting sound waves.
- **Classroom Implementation Reflection:** Students have formulated research questions and hypotheses that are specific, measurable, and testable. For instance, they may predict that porous materials like foam will exhibit greater sound attenuation compared to denser materials like metal. These hypotheses, grounded in their understanding of wave behavior, provide a clear foundation for experimental design.
- **General Learning Outcomes:** The learning outcomes from this step are both conceptual and practical. Conceptually, students have deepened their knowledge of sound physics, including intensity, frequency, and the decibel scale. They have also linked these principles to real-world applications, such as noise pollution and soundproofing in urban planning. Practically, students have developed essential scientific skills: conducting a literature review, formulating hypotheses, and critically evaluating variables. Additionally, they have practiced collaborative problem-solving by engaging in group discussions and refining their ideas through peer feedback. This step has highlighted the importance of preparation in scientific inquiry, showing how a strong theoretical foundation enables a focused and methodical experimental approach. Students are now equipped with the knowledge and tools necessary to transition to the next phase: testing their hypotheses through systematic experimentation.



To conclude this phase, students will engage in a discussion centered on open-ended questions. These questions are designed to encourage deeper reflection on the study and its broader implications. Several questions can be opened for discussion:

- How might the frequency of sound (high-pitched vs. low-pitched) influence the effectiveness of different materials in attenuating sound?
- Why are some materials, such as foam, commonly used in soundproofing, while others, like metal, are not?

- How does the concept of sound attenuation apply to different environments, such as recording studios, classrooms, or residential buildings?
- What are the environmental trade-offs of using synthetic soundproofing materials compared to natural ones?
- How can advances in material science improve the effectiveness and sustainability of soundproofing materials?
- How does sound behave in non-air environments, such as underwater or in outer space?
- What are the limitations of the decibel scale when measuring sound in complex, noisy environments?
- How might future urban planning integrate soundproofing to create quieter, more livable cities?
- In what ways could sound attenuation technology contribute to reducing noise pollution in public transportation systems?
- Could cultural or societal differences influence how communities prioritize and address noise pollution issues?

Step 2 - Experimental Design and Data Collection

The goal of this phase is to transition students from theoretical exploration to practical experimentation. Students will use their knowledge of sound waves and attenuation, combined with the research question and hypothesis formulated in Step 1, to design and execute a methodical experiment. This hands-on phase introduces essential scientific practices, such as precision in measurement, systematic data collection, and troubleshooting.

Background and description of the problem to be solved in this step: This step transitions from theoretical preparation to hands-on experimentation. Students will construct their experimental setup, test their hypotheses, and systematically collect data to explore how materials attenuate sound. By applying scientific rigor to their methods, students will ensure their findings are reliable and meaningful.

Learning Objectives: Students are expected to achieve the following key objectives:

1. **Reinforce theoretical knowledge through application:** By constructing and testing an experimental setup, students will deepen their understanding of sound intensity, the decibel scale, and the ways in which material properties influence sound behavior. For example, they will directly observe how porous materials absorb sound or how dense materials reflect it.
2. **Develop scientific methodology:** This phase provides an opportunity to implement a step-by-step protocol. Students will learn to control variables, such as the distance between the sound source and microphone, and ensure repeatability by conducting multiple trials. They will also refine their ability to connect the experimental setup to the hypothesis, ensuring that each test produces meaningful data.
3. **Learn measurement and data handling techniques:** Students will measure sound intensity in decibels using a programmable microcontroller and microphone. They will practice recording, organizing, and verifying data, creating structured tables for sound intensity, material properties, and calculated attenuation.
4. **Strengthen critical thinking and problem-solving skills:** As students encounter challenges, such as external noise interference or inconsistent measurements, they will develop strategies to troubleshoot and refine their approach. For example, they might adjust microphone placement or repeat tests in quieter conditions to improve accuracy.
5. **Explore the connection between scientific inquiry and real-world problems:** Students will recognize how sound attenuation plays a role in addressing noise pollution in urban settings, improving acoustic design in buildings, and enhancing comfort in everyday environments. This practical application of scientific concepts highlights the relevance of their work to sustainability and urban planning.



Conceptualisation

This phase connects our hypothesis from Step 1 to a specific, testable experiment. Students will clearly define their test parameters and explain why their chosen variables matter for understanding sound attenuation. By anchoring their experiment in fundamental principles of sound and material properties, students ensure their work delivers both scientific and practical insights.

To engage students and align their thinking with the experimental phase, consider posing the following questions:

- How can we ensure that our experimental setup accurately measures sound attenuation?
- What factors (e.g., thickness, density, or material type) might influence sound attenuation, and how can we isolate their effects?

- How can we minimize errors in our measurements, such as background noise or equipment inconsistencies?
- What practical applications can we envision for the results of this experiment?
- How will we know if our data supports or refutes our hypothesis?

The experiment tests how specific material properties—type, thickness, and density—affect sound attenuation. Our goal is to measure and compare how effectively different materials reduce sound intensity, using decibels as our unit of measurement.

The **independent variable (IV)** is the material property we test, including:

- Material type (foam, wood, metal, fabric)
- Material thickness (1 cm, 2 cm, 3 cm samples)
- Material density (low-density vs. high-density foam)

The **dependent variable (DV)** is the sound intensity reduction (in decibels). We calculate attenuation by comparing sound levels with and without the material present.

We control these additional variables:

- Distance between sound source, material, and microphone
- Buzzer frequency and volume
- Environmental noise levels

This experiment reveals how sound interacts with materials, offering both scientific and practical value:

1. **Scientific Understanding :** Students observe and measure how sound waves behave when encountering materials. Porous materials like foam absorb sound waves and convert them to heat, while dense materials like metal reflect them. Through systematic testing, students grasp the principles of sound propagation and energy transformation.
2. **Practical Applications :** Our findings directly apply to real-world challenges: reducing urban noise pollution, enhancing building acoustics, and developing sustainable soundproofing. Students learn how scientific principles shape architectural design and environmental planning.
3. **Testing the Hypothesis :** We evaluate our Step 1 hypothesis with measurable data. For example, if we predict that "foam attenuates sound better than metal due to its porous structure," our measurements will either support or challenge this prediction, building scientific reasoning skills.

Students apply their theoretical knowledge to predict material performance. For instance:

- Materials with **higher density** (like steel) primarily reflect sound, resulting in less attenuation
- **Thicker materials** create stronger sound barriers, increasing attenuation
- **Porous materials** absorb and dissipate sound energy, enhancing attenuation

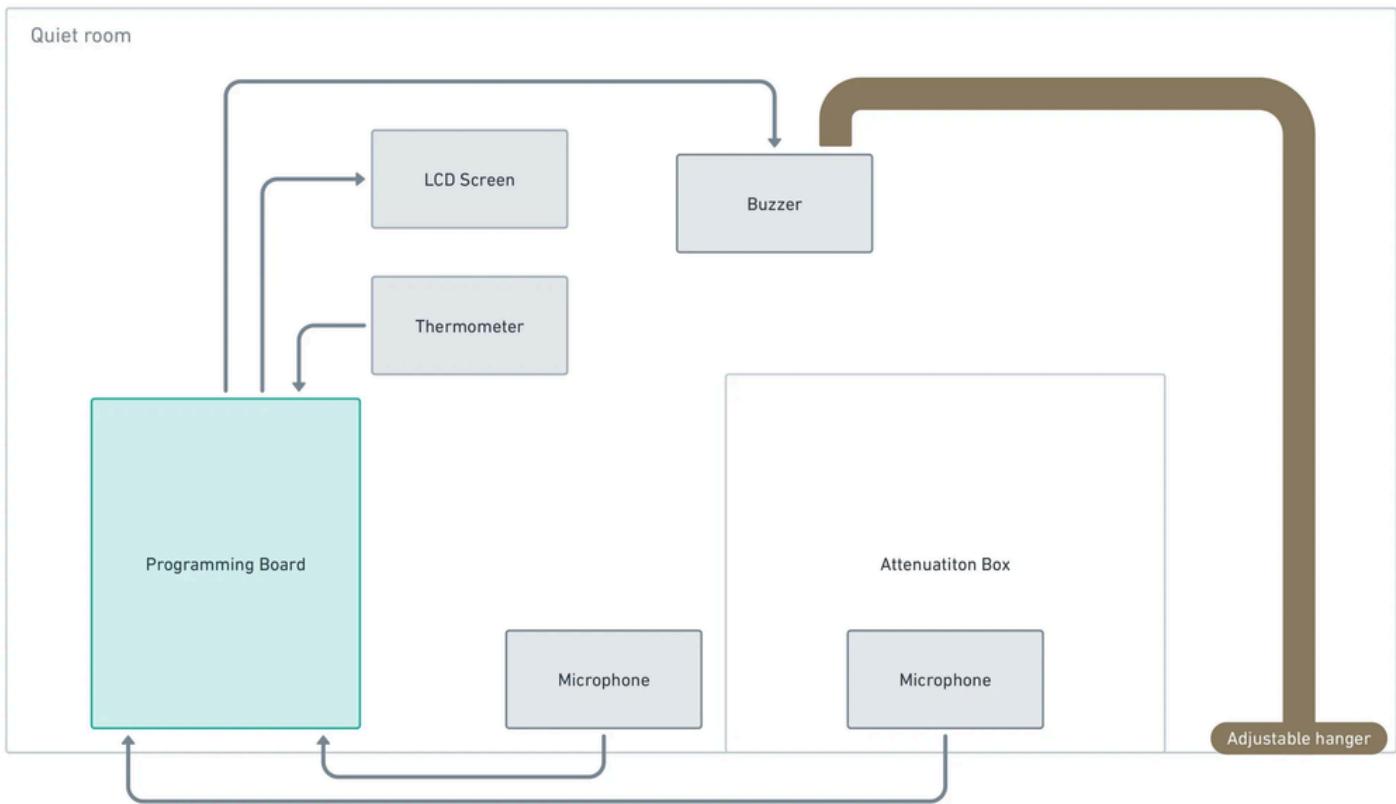
These connections help students justify their material choices and experimental design.

Key questions to consider:



- How do material properties affect sound wave interaction?
- Why measure sound intensity in decibels?
- How do frequency and amplitude influence sound attenuation?
- How does our experiment test our hypothesis?
- What real-world problems could our findings help solve?

This conceptual framework helps students grasp the purpose of their experiment while ensuring their work connects scientific principles to practical applications.



Students Investigation

In this phase, students move from planning to executing their experiment. They will implement a structured protocol to measure sound attenuation by different materials, ensuring their methodology is rigorous, reliable, and aligned with their hypothesis. The focus is on precision, repeatability, and clear data collection.

Building the Experimental Setup

The experimental setup must be designed to isolate the interaction of sound waves with the material being tested. Key components include:

- **Sound Source:** A buzzer emitting a constant frequency and amplitude provides a controlled sound wave for testing. The frequency of the buzzer should be chosen to simulate real-world sounds, such as typical environmental or indoor noise levels (e.g., 500–1000 Hz).
- **Microphone and Microcontroller:** A microphone connected to a programmable microcontroller will measure sound intensity in decibels (dB). The microcontroller processes and displays the data, either on an LCD screen or through a computer interface.
- **Test Materials:** Students will test a variety of materials with differing properties, such as foam, wood, metal, and fabric. Materials should vary in thickness and density to explore their effects on attenuation.
- **Controlled Environment:** To minimize interference, the experiment should take place in a quiet room where external noise is reduced. Ensure consistent lighting and environmental conditions to avoid fluctuations in sensor readings.

Step-by-Step Protocol

1. **Calibration:**
 - Begin by calibrating the microphone and sound source. Measure the reference sound intensity (baseline) without any material between the source and the microphone. Record this as the starting intensity.
 - Confirm that the sound source emits a consistent tone and the microphone records stable readings.
2. **Testing Materials:**
 - Place the test material between the sound source and the microphone at a fixed distance (e.g., 10 cm between the source, material, and microphone). Ensure alignment to avoid sound wave deflection.

- Record the sound intensity after the material in decibels. This value represents the sound transmitted through the material.
- Repeat the measurement for each material, ensuring consistent placement and alignment.

3. Data Collection for Multiple Trials:

- For each material, conduct at least three trials to account for variability. Record the results of each trial, and calculate the average intensity for greater accuracy.
- Repeat the process for materials with varying thicknesses or densities, keeping all other variables constant.

4. Calculating Attenuation:

- Use the formula: **Attenuation (dB) = Reference Intensity (dB) - Transmitted Intensity (dB)**
- Record the attenuation for each material and configuration in a structured data table.

Recording and Organizing Data

Students will create a systematic data table to capture their observations:

Material Type	Thickness (cm)	Density (g/cm ³)	Reference Intensity (dB)	Transmitted Intensity (dB)	Attenuation (dB)
Foam	1	0.03	80	50	30
Wood	2	0.60	80	65	15
Metal	0.5	7.80	80	75	5



To help you program the appropriate sensor, refer to the section “**Practical implementation 2 - Displaying Data on a Screen**”.

Encourage students to include observations about each material, such as texture, rigidity, or potential defects that could influence the results.

During the experiment, students may encounter issues such as inconsistent measurements or external noise interference. Strategies for addressing these challenges include:

- **Recalibration:** Ensure the sound source and microphone are functioning correctly.
- **Environmental Control:** Minimize noise by conducting the experiment in a quieter space or using sound-dampening barriers.
- **Repetition:** Perform additional trials if results seem inconsistent.

Encourage students to work collaboratively, comparing setups and results across groups.

Class discussions can focus on:

- How to improve alignment and placement for consistent readings.
- Whether observed trends align with their hypotheses.
- Any unexpected patterns and their possible explanations.

By the end of this phase, students will have:

1. Collected a complete dataset that quantifies the sound attenuation properties of different materials.
2. Practiced precision in experimental design and execution.
3. Developed a structured approach to data collection and analysis, ensuring reliable results for Step 3.

This hands-on investigation fosters a deeper understanding of sound attenuation and prepares students to analyze their findings critically in the next phase.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** By completing this phase, students have moved from theoretical preparation to practical experimentation, collecting valuable data to address their hypotheses. Through systematic measurements of sound intensity and attenuation, they have begun to uncover how material properties—such as type, thickness, and density—affect the reduction of sound waves. The collected data now serves as the foundation for validating or refining their hypotheses in the subsequent analysis phase.
- **Classroom Implementation Reflection:** The experimental results provide preliminary insights into the elements of response to the hypotheses. For instance, students may observe trends such as foam attenuating sound more effectively than wood or metal, or thicker materials providing greater attenuation. These observations offer measurable, evidence-based answers to their research questions while fostering critical thinking about potential outliers or inconsistencies in their data.
- **General Learning Outcomes:** The learning outcomes from this phase are multifaceted:
 - a. **Scientific Methodology:** Students have applied a structured approach to experimentation, including defining variables, controlling conditions, and ensuring repeatability.
 - b. **Data Collection and Handling:** They have developed skills in using measurement tools, recording results systematically, and organizing data for subsequent analysis.
 - c. **Problem-Solving and Adaptability:** By addressing challenges such as noise interference or inconsistent results, students have improved their ability to troubleshoot and refine their methods.
 - d. **Collaborative Skills:** Group work has encouraged shared responsibility, peer learning, and the ability to critically evaluate protocols and results.



To deepen understanding and encourage reflection, students can discuss the following questions:

- How do the experimental results align with their initial hypotheses? Were there any surprises or unexpected patterns?
- How might the setup be improved to ensure even greater accuracy and reliability in future experiments?
- Are there other material properties, such as texture or flexibility, that could influence sound attenuation but were not tested?
- How do the findings relate to real-world applications, such as designing soundproof buildings or mitigating urban noise pollution?
- How could this experiment be adapted to test sound attenuation for different sound frequencies or amplitudes?

This step has solidified the connection between theory and practice, equipping students with the tools to interpret and analyze their findings critically in Step 3. It has also highlighted the iterative nature of scientific investigation, where each phase builds on the insights and challenges of the previous one.

Step 3 - Data Analysis and Interpretation

Background and description of the problem to be solved in this step: In this step, students transition from data collection to analysis, interpreting their results to validate or refine their hypotheses. After collecting data on the sound attenuation properties of various materials, students now enter the critical phase of analyzing and interpreting their findings. The goal is to evaluate whether the experimental results support their initial hypotheses and to identify patterns or trends that explain the behavior of sound when interacting with different materials. This phase challenges students to connect their observations to the theoretical principles explored earlier while addressing potential inconsistencies or limitations in their data.

Learning Objectives:



- **Core Competencies:**
 - Organizing and analyzing experimental data to identify patterns and trends.
 - Testing the validity of hypotheses by comparing results with predictions.
 - Interpreting results within the context of sound physics and material properties, including attenuation, absorption, and reflection.
 - Reflecting on limitations, anomalies, and potential sources of error to evaluate the reliability of the findings.
- **Auxiliary Competencies:**
 - Developing skills in visual representation of data, such as creating graphs or tables.
 - Applying statistical reasoning, such as calculating averages or comparing data sets.
 - Communicating findings effectively, including providing evidence-based explanations.
 - Strengthening critical thinking by discussing broader implications, such as the applications of soundproofing in urban environments or noise pollution mitigation.

This phase encourages students to approach their data with curiosity and rigor, treating their findings not just as answers but as a starting point for deeper scientific inquiry and real-world connections.

Conceptualisation

The purpose of this phase is to analyze the collected data to draw meaningful conclusions about sound attenuation and its relationship with material properties. Students will connect the patterns in their results to their hypotheses, identifying whether the experimental findings align with their initial predictions. This phase emphasizes linking data interpretation to scientific reasoning and exploring its broader significance.

Students are analyzing how well different materials attenuate sound by examining their measured data. This involves:

- **Quantifying sound attenuation:** Calculating the reduction in sound intensity for each material, expressed in decibels.
- **Comparing material effectiveness:** Determining which materials (e.g., foam, wood, metal) are most effective at reducing sound intensity.
- **Investigating the impact of material properties:** Exploring how thickness, density, or structure affect a material's ability to attenuate sound.

The analysis should focus on identifying patterns in the data. For example, students may observe that porous materials, such as foam, consistently attenuate more sound than rigid materials like metal. Similarly, they may find that increasing the thickness of a material leads to greater attenuation.

The analysis serves several key purposes:

- **Testing the Hypotheses:** The analysis allows students to evaluate whether their experimental results support or refute their initial hypotheses. For example: If students hypothesized that “thicker materials attenuate more sound,” they can validate this by observing a positive correlation between thickness and decibel reduction.
- **Deepening Understanding of Sound Behavior:** By interpreting their findings, students will better understand how sound waves interact with different materials. For instance, porous materials absorb sound energy and convert it into heat, whereas dense materials often reflect sound. Analyzing these interactions helps students link their results to the principles of wave propagation and energy transformation.
- **Highlighting Real-World Applications:** The findings of this analysis have practical implications for addressing noise pollution, improving building acoustics, and designing sustainable soundproofing solutions. By understanding which materials are most effective, students can connect their results to broader societal challenges and engineering solutions.

Students will approach the analysis by systematically organizing their data and using visual tools to identify trends and relationships. Steps include:

- **Summarizing Results:** Students will calculate averages and standardize their measurements to ensure consistency.
- **Visualizing Data:** Graphs and charts will help students identify clear patterns, such as whether one material consistently performs better than others or how attenuation changes with thickness.
- **Relating to Hypotheses:** Each result will be examined in the context of the initial hypotheses to determine whether the experimental evidence supports the predictions.

Guiding Questions for Analysis

To deepen their critical thinking, students can reflect on the following questions:

- Do the results align with their initial hypotheses? If not, why might this be the case?
- Are there any unexpected trends or outliers in the data? How might these be explained?
- How do their findings compare to their theoretical understanding of sound attenuation?
- What do the results suggest about the role of material properties, such as porosity or density, in influencing sound behavior?
- How might this experiment inform real-world applications, such as noise reduction in urban planning or architectural design?

Students Investigation

Organizing Data

Students will begin by reviewing their raw data, ensuring it is complete and consistent across trials. Data should be organized into tables for clarity.

For example:

Material	Thickness (cm)	Density (g/cm ³)	Reference Intensity (dB)	Transmitted Intensity (dB)	Attenuation (dB)
Foam	2	0.03	80	50	30
Wood	2	0.60	80	65	15

Students should calculate the average attenuation for each material and configuration to account for variability across trials.

Visualizing Results

Students will create graphs to highlight trends and relationships in their data. Examples of visualizations include:

- **Bar Graphs:** To compare attenuation values across different materials.
- **Scatter Plots:** To examine the relationship between thickness or density and attenuation.
- **Line Graphs:** To show trends in attenuation as material properties change (e.g., increasing thickness).

Interpreting Results

Students will analyze their visualized data to identify patterns. Key questions to address include:

- **Which material attenuated sound most effectively?**
- **Is there a clear relationship between thickness or density and attenuation?**
- **Were the results consistent across trials, or were there significant outliers?**

Encourage students to interpret their findings in light of their theoretical knowledge. For instance, if foam attenuates more sound than metal, they can explain this by referencing the material's ability to absorb sound waves versus reflecting them.

Addressing Limitations

Students will reflect on any inconsistencies or unexpected results. Possible limitations might include:

- Measurement errors due to external noise or equipment issues.
- Variability in material quality or placement.
- Limitations in the experimental setup, such as the inability to test higher frequencies.

Students will discuss their findings as a class or in groups, comparing results and interpretations.

Teachers can guide reflection with questions such as:

- Do the results support or refute the hypothesis? Why?
- Were there any surprising trends, and how can they be explained?
- What would you do differently if you were to repeat the experiment?
- How do the findings relate to real-world applications of soundproofing?

This phase strengthens students' ability to think critically, analyze data, and communicate their findings effectively, setting the stage for a meaningful discussion of broader implications.

Reflecting on the Experimental Process

- **Group Discussion:** Each group will present their findings to the class and discuss how their data compared to their initial hypotheses. This will provide an opportunity to identify common themes across the different groups' studies.
- **Bias, Limitations, and Improvement:** Teachers should lead a discussion on the limitations of the data collection process, including potential biases, the constraints of the sample size, and how these factors might influence the reliability of the results.

Students should consider how limitations such as short data collection periods, unaccounted environmental changes, and observer influence could impact their findings.

They should also discuss strategies for minimizing these limitations in future experiments, such as conducting the study over a longer duration, collecting more extensive data, or adding controls for environmental variables.

Conclusion & Further Reflexion

- **Knowledge Mobilized:** Students will learn about organizing and analyzing scientific data, applying statistical methods to real-world datasets, and recognizing the limitations of small-scale studies.
- **Classroom Implementation Reflection:** This phase helps students understand how raw data can be transformed into meaningful information. It also emphasizes the importance of data integrity, transparency, and critical reflection on findings.
- **General Learning Outcomes:**
This phase has fostered several key learning outcomes:
 - **Data Analysis Skills:** Students have learned to organize raw data, create meaningful visualizations, and interpret patterns.
 - **Critical Thinking:** By comparing their findings with theoretical principles, students have developed the ability to reason scientifically and evaluate evidence.
 - **Reflection on Experimental Design:** Students have identified limitations in their methodology and recognized areas for improvement, such as increasing sample sizes or testing additional variables.
 - **Real-World Connections:** The experiment has highlighted the relevance of sound attenuation in solving real-world challenges, from noise pollution mitigation to architectural design.
 - **Communication Skills:** Students have practiced presenting their findings clearly and effectively, justifying their conclusions with evidence.



The analysis phase has allowed students to connect their experimental data to their hypotheses and deepen their understanding of sound attenuation. By examining the relationships between material properties—such as type, thickness, and density—and their ability to reduce sound intensity, students have gained meaningful insights into the behavior of sound waves and the effectiveness of different materials as sound insulators.

Through their analysis, students have provided evidence-based responses to their hypotheses. For instance:

- If they hypothesized that "foam will attenuate sound more effectively than wood or metal due to its porous structure," their data likely confirms or refutes this with measurable attenuation values.
- If they hypothesized that "thicker materials will attenuate more sound than thinner materials," they can verify this by identifying trends in their graph or table.

These findings are not just answers but stepping stones to broader discussions, encouraging students to think critically about why certain materials performed better or worse than expected.

To extend their learning and broaden their perspective, students can consider the following questions:

- How do the findings align with their initial expectations? Were there any surprises or inconsistencies?
- Could other material properties, such as flexibility or surface texture, influence sound attenuation? How could these be tested?
- What are the limitations of using decibels as a measure of sound intensity? Are there other metrics worth exploring?
- How could this experiment be adapted to study the effects of sound frequency on attenuation?
- How do these findings relate to real-world challenges, such as reducing noise pollution in urban areas or designing better soundproof spaces?
- What could be the environmental impact of using these materials at scale for soundproofing purposes?
- How does the understanding of sound attenuation apply to other fields, such as underwater acoustics or aerospace engineering?

This phase emphasizes the iterative nature of scientific inquiry, showing students that analysis is not just about validating hypotheses but also about uncovering new questions and possibilities. By reflecting on their findings and connecting them to practical applications, students gain a deeper appreciation for the role of science in addressing real-world problems.

As they transition to presenting and consolidating their results, students are encouraged to view their experiment as part of a larger conversation on how to create quieter, more sustainable, and more comfortable living spaces.



Practical Implementation 1

Measuring the Intensity of Sound



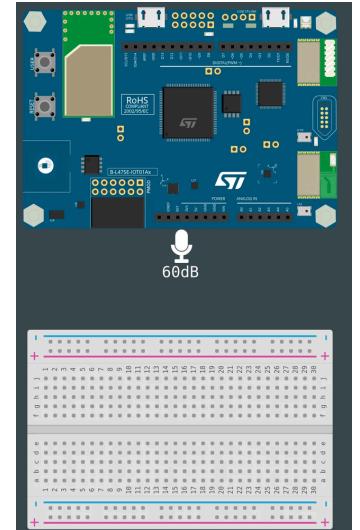
Instructions for wiring and using the micro:bit board

Using the microphone

We will be using the microphone present on the STM32 IoT Node Discovery, so there's no need to make any connections.

Connecting the board to the computer

Using your USB cable, connect the board to your computer by using the micro-USB ST-LINK connector (on the upper right corner of the board). If everything goes well, you should see a new drive called DIS_L4IOT appear on your computer. This drive is used to program the board by simply copying a binary file.



Opening MakeCode

Go to the Let's STEAM MakeCode editor. On the home page, create a new project by clicking on the "New Project" button. Give your project a more meaningful name than "Untitled" and launch your editor. Resource: makecode.lets-steam.eu

Installing the extensions

After creating your new project, you will get the default "ready-to-use" screen and will need to install an extension. You will see the black **ADVANCED** button at the bottom of the column of different block groups. If you click on **ADVANCED**, additional block groups will appear. At the bottom, there's a gray box called **EXTENSIONS**. Click on this button. In the list of available extensions, you can easily find the **serial** extension, which will allow you to display the value measured by the microphone in the console. If it's not directly available on your screen, you can search for it using the search tool. Click on the extension you want to use, and a new block group will appear on the main screen.



Code

Here is the Javascript code used to program a STM32 board in order to regularly collect the sound level from the embedded microphone.

```
Serial.attachToConsole()  
forever( function(){  
    Serial.writeValue("Decibel", input.decibel());  
    pause(200)  
})
```

Programming the board

In the MakeCode JavaScript editor, copy/paste the code available in the "Code it!" section below. If you haven't already, give a name to your project and click on the "Download" button. Copy the binary file onto the DIS_L4IOT drive and wait for the board to finish flashing.

Run, modify, play

Your program will automatically run whenever you save it or reset your board (press the RESET button).



Practical Implementation 2

Displaying Data on a Screen



Instructions for wiring and using the micro:bit board

Connecting the screen

To connect the LCD screen, we will use the I2C bus with the following convention:

- Black for GND (GND)
- Red for VCC (5V)
- Violet for SDA (D14)
- Green for SCL (D15)

Resources:

<https://en.wikipedia.org/wiki/I2C>

https://en.wikipedia.org/wiki/Serial_Peripheral_Interface

<https://www.sparkfun.com/qwiic>

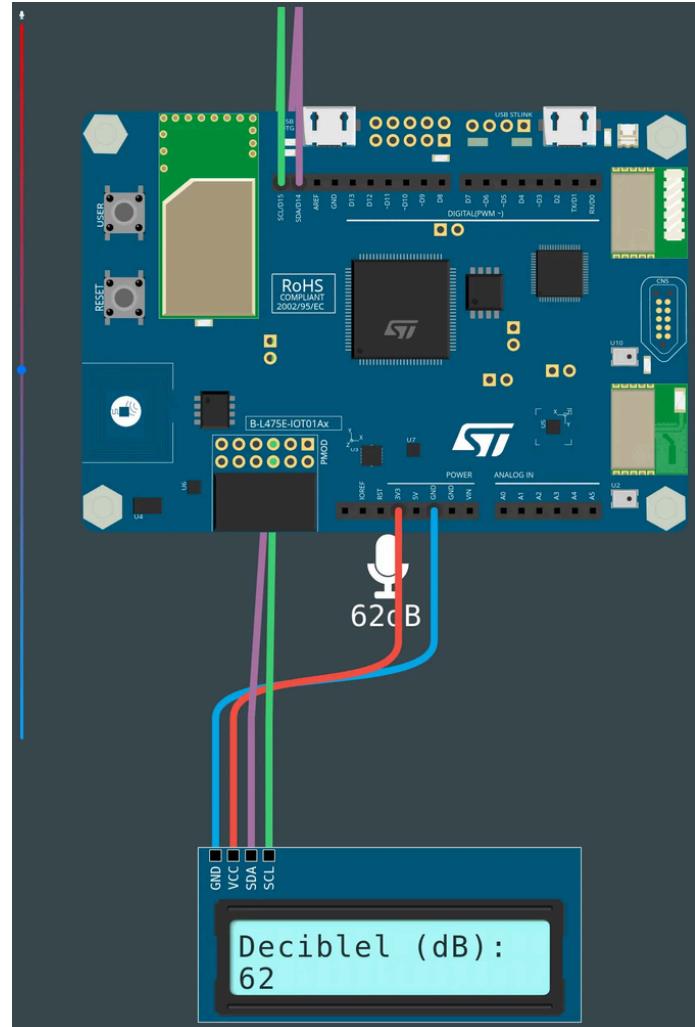
<https://learn.adafruit.com/introducing-adafruit-stemmaqt/what-is-stemma-qt>

Connecting the board to the computer

Using your USB cable, connect the board to your computer using the micro-USB ST-LINK connector (located in the top-right corner of the board).

If everything goes well, you should see a new drive called DIS_L4IOT appear on your computer.

This drive is used to program the board by simply copying a binary file.



Opening MakeCode

Go to Let's STEAM's MakeCode editor. On the homepage, create a new project by clicking on the "New project" button. Give your project a more expressive name than "Untitled" and launch your editor. Resource: makecode.lets-steam.eu

Installing extensions

After creating your new project, you will get the default "ready-to-use" screen and you will need to install an extension.

You will see the black **ADVANCED** button at the bottom of the column of different block groups. If you click on **ADVANCED**, additional block groups will appear. At the bottom, there is a gray box called **EXTENSIONS**. Click on this button.

In the list of available extensions, you can easily find the **lcd_i2c** extension that will be used for this activity. The **lcd_i2c** extension will allow you to display data on a screen. If it is not directly available on your screen, you can search for it using the search tool. Click on the extension you want to use and a new block group will appear on the main screen.



Code

Here is the Javascript code used to program a STM32 board in order to regularly collect the sound level from the embedded microphone.

```
lcd_i2c.initScreen()
lcd_i2c.setCursor(0, 0);
lcd_i2c.ShowString("Decible1 (dB):")

forever(function () {
    lcd_i2c.setCursor(0, 1);
    lcd_i2c.ShowNumber(input.decibel());
    lcd_i2c.ShowString("    ");
    pause(200)
})
```

Programming the board

In the MakeCode JavaScript editor, copy/paste the code available in the section above. If you haven't already, give a name to your project and click on the "Download" button. Copy the binary file onto the DIS_L4IOT drive and wait for the board to finish flashing.

Run, modify, play

Your program will automatically run whenever you save it or reset your board (press the RESET button).



Exploring the issue through other initiatives

Sound pollution is a complex issue that extends beyond the classroom, through environmental, societal, and technological dimensions. Below are some initiatives and projects that can inspire further exploration:

Explore Soundscapes and Urban Noise Mapping



Encourage students to use smartphone apps like "[SoundPrint](#)" or "[Hush City](#)" to map quiet spaces or noisy hotspots in their community. Students can investigate how urban planning affects noise pollution and propose ways to design quieter cities. [Hush City App](#)

Activity Idea: Create a local "quiet map" by recording noise levels in different urban areas and identifying zones that need improvement.

Learn from the Noise Barrier Innovations



Explore real-world examples of soundproofing technologies, such as highway noise barriers or vegetative walls. Students can research how natural materials, such as hedges or moss walls, can reduce noise while improving urban aesthetics and air quality. [Noise Barriers by FHWA](#)

Activity Idea: Design a sustainable noise barrier for a local problem area using a mix of natural and engineered solutions.

Investigate the Impact of Underwater Noise Pollution



Sound pollution is not just a terrestrial issue; underwater noise from ships and industrial activities affects marine ecosystems. Students can research how technologies, such as quieter ship propellers, are being developed to reduce noise pollution underwater. [Ocean Noise: National Oceanic and Atmospheric Administration \(NOAA\)](#)

Activity Idea: Simulate underwater sound propagation using tanks and vibrations to explore how sound travels differently in water versus air.

Engage with Policies on Noise Regulation



Students can learn how policies, such as the EU's [Environmental Noise Directive](#), aim to control sound pollution. They can explore local noise ordinances or global standards to understand how governments regulate noise. [European Environment Agency: Environmental Noise](#)

Activity Idea: Hold a mock debate on balancing economic development (e.g., airports, highways) with the need for noise reduction in communities.

Experiment with Materials for Acoustic Design



From recycled plastics to 3D-printed soundproof panels, new materials are being developed to tackle sound pollution sustainably. Students can experiment with upcycled or unconventional materials to create their own soundproofing solutions. [10 Acoustic Innovations](#)

Activity Idea: Prototype an acoustic panel using everyday or recycled materials and measure its effectiveness in reducing noise.

Explore Nature's Role in Noise Reduction



Forests, trees, and vegetation act as natural sound barriers, absorbing noise and improving overall well-being. Students can investigate the role of green spaces in noise mitigation and propose how cities can incorporate more "green soundproofing." [Influence of Green Areas on the Urban Sound Environment](#)

Activity Idea: Test the sound absorption capabilities of different plants or create a small-scale "green wall" for a classroom experiment.

Explore Cultural and Artistic Dimensions of Sound



Noise pollution has cultural and psychological dimensions. Students can explore how excessive noise impacts well-being or learn how artists use soundscapes to reflect environmental challenges. [World Soundscape Project](#)

Activity Idea: Record soundscapes in their local area and create an audio collage to compare noisy and quiet environments, reflecting on their emotional impact.

Explore Emerging Noise-Cancelling Technologies



Students can research how active noise cancellation (ANC) is used in headphones and other devices. They could experiment with sound phase cancellation to demonstrate the principles of ANC. [How Noise-Cancelling Technology Works](#)

Activity Idea: Build a simple ANC system using microphones and speakers to observe its effect on sound waves.



Bibliography

Books

- **Rossing, T. D., & Fletcher, N. H. (2004).** *Principles of Vibration and Sound*. Springer : This book provides an accessible introduction to the physics of sound and vibration, including how materials interact with sound waves. <https://link.springer.com/book/10.1007/978-1-4757-3822-3>
- **Everest, F. A., & Pohlmann, K. C. (2021).** *Master Handbook of Acoustics (7th Edition)*. McGraw-Hill Education : A comprehensive resource on acoustics, covering topics from soundproofing to room acoustics and material properties. <https://www.accessengineeringlibrary.com/content/book/9781260473599>

Research Articles

- **Ver, I. L., & Beranek, L. L. (2006).** "Noise and Vibration Control Engineering: Principles and Applications." : A technical guide to noise control engineering, including practical applications for soundproofing and attenuation. <https://onlinelibrary.wiley.com/doi/book/10.1002/9780470172568>
- **L. Cao, Q. Fu, Y. Si, B. Ding, J. Yu (2018).** "Porous materials for sound absorption": This article reviews studies on how porous materials absorb sound and discusses their practical applications in noise control. https://www.researchgate.net/publication/325614788_Porous_materials_for_sound_absorption

Web Resources

- [European Environment Agency \(EEA\) – Environmental Noise Pollution](#) : A resource on noise pollution data and regulation across Europe, useful for exploring real-world mitigation strategies.
- [Decibel X App](#) : A mobile app for measuring sound levels in real-time, useful for practical classroom experiments.

Educational Videos and Multimedia

- ["How Soundproofing Works"](#) : A short, engaging video explaining the principles of soundproofing and how materials block or absorb sound.
- ["The Science of Sound Videos: Listen to this!" – National Geographic Kids](#) : A visually engaging overview of how sound travels and interacts with different environments.

Standards and Guidelines

- **ISO 717-1: Acoustics – Rating of Sound Insulation in Buildings and of Building Elements** : The international standard for measuring and rating sound insulation properties of materials. <https://www.iso.org/standard/51968.html>