Global Weather Sound: Sonification of Weather Data

Subjects and topics:

- Physics: Weather parameters: Atmospheric Pressure, Humidity, Temperature;
- Mathematics: Data Analysis and Statistics;
- Information and Communication Technologies: Digital Literacy, Programming, Data Sonification, Multimedia, Electronics;
- Arts: Sound Design.

Duration: 4 x 90 min sessions.

Grade level: 6th - 12th

Summary

In Global Weather Sound, students and teachers will be stimulated to learn and experiment with weather analysis by designing and building their own weather station able to focus on monitoring atmospheric pressure in their locations allowing them to understand weather patterns in a new way. Through this hands-on project, students will assemble sensors, program them to collect atmospheric data, and connect their stations to a shared online platform using ThingSpeak.
The final global result will be displayed through a unique collaborative sound output in the form of a website. In this globally accessible web platform data from all participants' weather stations are collected and transformed into sound, allowing students to 'hear' atmospheric changes over time and across different locations. The project will culminate with student presentations on their findings, encouraging them to communicate their data in a format that is both scientifically informative and creatively engaging.

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FEEL

The Feel phase is the first step in design thinking, focusing on research and understanding a problem's impact on individuals and communities. It encourages empathy, curiosity, and critical thinking while prompting students to generate questions related to their curriculum, such as the importance of environmental protection. By exploring these questions, students engage with various STEAM concepts and conduct research through community surveys, expert visits, and online activities to deepen their understanding of the issue.
We suggest discussing the context of this sonification system, for the teachers and students to be aware of the issue, what the media say about climate change, and what the scientific debate is about.

Why the atmospheric pressure parameter

Learning about atmospheric pressure and weather patterns is essential for understanding how these factors affect our daily lives, health, and environment. Atmospheric pressure influences weather conditions, including temperature, precipitation, and wind, which in turn impact agriculture, transportation, and community safety. By studying atmospheric pressure, students gain insights into how weather systems form and evolve, and they can better understand the science behind forecasts that help us prepare for changing conditions.

Comparing local atmospheric pressure with data from other locations enhances this learning by revealing how pressure differences drive weather changes. For instance, high and low-pressure systems in one area often move and influence weather in nearby regions, sometimes resulting in severe weather events like storms or rapid temperature changes. Observing these differences fosters a deeper understanding of regional and global weather patterns and demonstrates how interconnected our atmosphere is. This knowledge empowers students to make informed decisions about their environment, become more resilient to climate variability, and understand the broader implications of weather on communities worldwide.

The fact that climate issues are shared at global level is very important as there are many concerns about climate change. Weather and climate are interconnected concepts: the statistical analysis of trends of the first defines the latter after at least 30 years of observations.

Resources:

- Making data sing | Margaret Anne Schedel | TEDxSBU
- How does atmospheric pressure affect weather?
- Sonification of Aeolus

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Weather and Meteorology Science Videos and Virtual Labs - YouTube Playlist
WeatherChimes: An Open IoT Weather Station and Data Sonification System
Atmospherics/Weather Works: A Spatialized Meteorological Data Sonification Project | Request PDF

RESULTS OF THE FEEL PHASE:

By the end of your implementation, you can add here results from this phase, including pictures, aha moments, quotes from students and other people involved, etc. This can inspire others to design projects as amazing as yours.

IMAGINE

Data sonification, the process of converting data into informative sounds, helps the end user, the analyst, and diverse audiences to understand and feel (hear) the results and the behaviour of data over time. It has great potential for enhancing comprehension of the phenomena addressed.

In this phase, the class should **learn about sonification** and its usefulness as an auditory display of data, complementary to data visualisation (graphs, animations, and other vision-based tools). Students can be encouraged to explore several of the sonification methods provided by the SoundScapes wiki, or others that they discover and develop. The aim at this stage is to understand the basic principles of sonification, the different techniques involved, and the potential impact of sound on data interpretation and understanding.

We suggest an activity to collect weather data from a sensor (atmospheric pressure) and through a device and store it on a shared online platform (Thingspeak).

Teachers and students will assemble the system and may analyse the evolution of the data of their locale as well as compare it to the data provided by other stations around the world.

The questions the class must deal with are:
where can we put a weather station exactly? outdoor/indoor?
How frequently should the data be updated?

Why is the pressure parameter an indicator of good or bad weather?

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Atmospheric pressure was chosen as characteristic data of the weather (high pressure sunny, low pressure cloudy). In the future other values like humidity and temperature could be added. Remember that when the sensor is calibrated atmospheric pressure can also indicate height above sea level.

The purpose of this activity is to have a sonification system whose output depends on the contribution of other schools and entities interested in joining. The aim is to stimulate the analysis of the evolution of weather in each locale compared to others in other locations in Europe and of the world.

As an example, students can develop a sonification system where the pitch of a sound generator is proportional to the level of atmospheric pressure registered by the device. To understand how this works, see a micro:bit (using a light level sensor).

Real-time simultaneous sonification of weather data allows us to compare data from different weather stations.

Moreover, students can extend the functionality of the device by including readings from other sensors like humidity, outdoor temperature, wind speed, and direction.

RESULTS OF THE IMAGINE PHASE:

By the end of your implementation, you can add here results from this phase, including pictures, aha moments, quotes from students and other people involved, etc. This can inspire others to design projects as amazing as yours. You can include here all the ideas from your students. This might help others to solve the problem too.

CREATE

The Weather Station we are going to build is a device able to receive atmospheric pressure data from a sensor, display it on a small screen and update a timeline graph of this data hosted on a web platform. The activity introduces the student to electronic circuit, programming, physical computation.

Here we describe the activity step-by-step.

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1) Materials Required

To start off and build our device we need to have the following components available:

- Raspberry Pi PicoW with heathers
- Grove - 4-Digit Display module
- Grove - Barometer Sensor (BMP280)
- 2 x 4 pin Male Jumper to Grove 4 pin Conversion Cable
- Breadboard

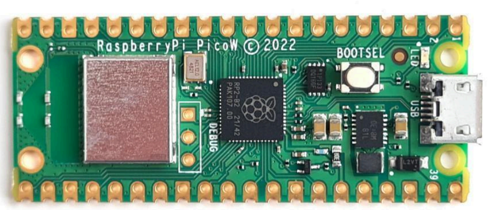
We additionally propose to have the device in a proper box to collect the components and protect it.

Enclosure:

- 3x 2M Screws with nuts
- 4x3M Screws
- Plastic Spacer
- Acrylic Glass Top and Bottom

Microcontroller Raspberry Pi Pico

We are going to work with a microcontroller called Pico. What is a microcontroller? It is a hardware circuit with a processor that runs a single program, basically, it is like a very simple computer with a single task. In this case, the task is to receive data from a sensor and send them to a web platform through the Internet.



Raspberry Pico

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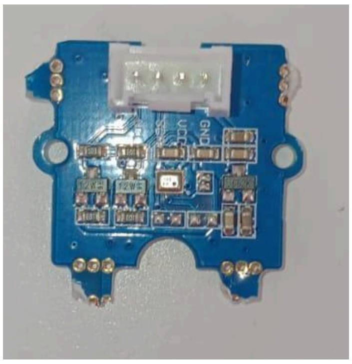
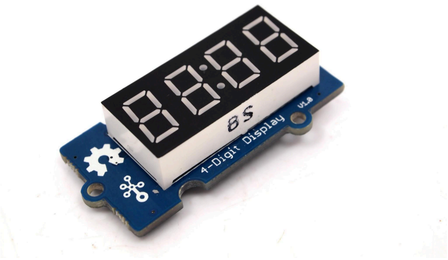
BMP280 Sensor

The **BMP280** is an absolute barometric pressure sensor, which is especially feasible for mobile applications. Its small dimensions and its low power consumption allow for the implementation in battery-powered devices such as mobile phones, GPS modules, or watches. The **BMP280** is based on Bosch's proven piezo-resistive pressure sensor technology featuring high accuracy and linearity as well as long-term stability and high EMC robustness.



Display 4-Digit

This component displays 4 numbers allowing the user to check if the device is working and read the value of the actual parameter. The display shows us the value of atmospheric pressure in hPa (Hectopascals) rounded to 4 digits (so for instance if the real value is 1011.76 it shows 1012). It is updated every minute. It also displays a quick error message in case the connection is lost or the value of the sensor is not being updated (ERR0) but the code in the microcontroller is able to restore the connection automatically. Or ERR1 when it is not possible to post the value on the Thingspeak channel.



Grove - 4-Digit Display module

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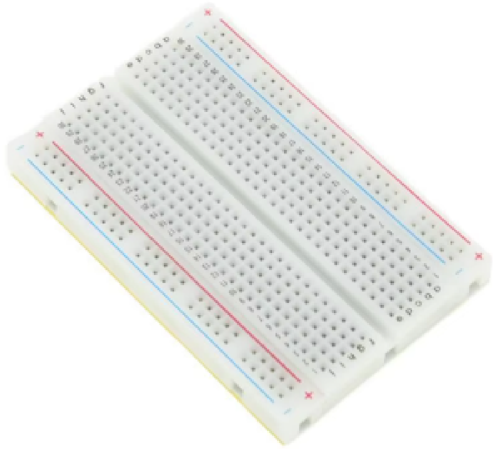
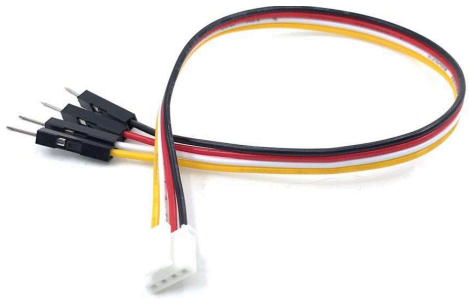
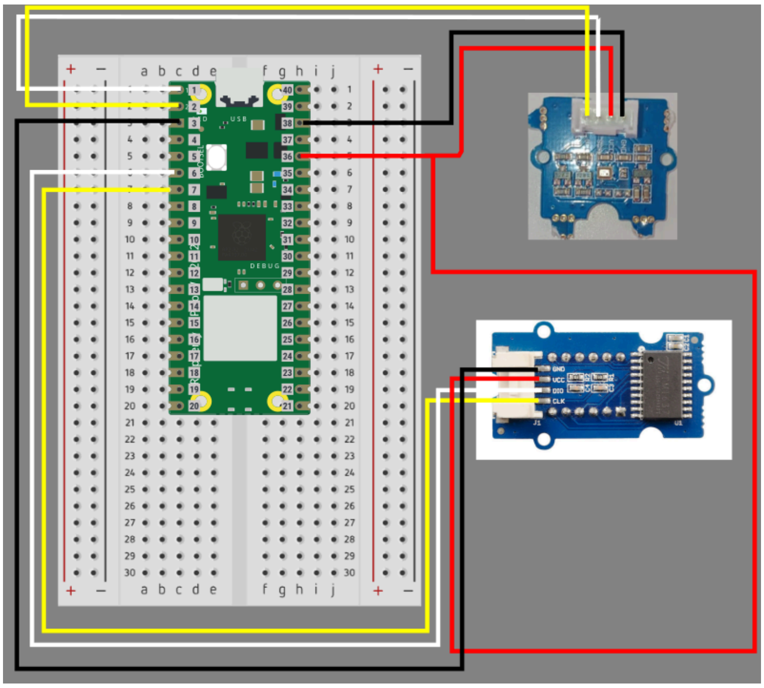
 Breadboard	 Jumpers

Breadboard and jumpers

The jumpers are cables that conduct electricity and are inserted into a breadboard to form the electrical circuit that connects components.

2) Assemble The Circuit



The circuit diagram (note that we put explicitly the numbers on the microcontroller. In the real device, you should count the correct number of the corresponding hole. The numbers on the breadboard are not of interest. The important thing is to make the connections as listed in the table)

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With the collected components we can start by building the electronic circuit, connecting the components with conductive cables (jumpers) with the help of a “breadboard” which allows the electricity to flow between the sensor, the display, and the microcontroller. It is easy and fun, just follow the scheme below:

- Place the PICO on the Breadboard
- Connect the Jumpers (cables) according to the picture

Pico pin	Sensor Pin	Sensor	Colour
2	SCL	BMP280	Yellow
1	SDA	BMP280	White
36	VCC	BMP280	Red
38	GND	BMP280	Black
7	CLK	Display	Yellow
6	DIO	Display	White
36	VCC	Display	Red
3	GND	Display	Black

3) Creating a ThingSpeak Account and Channel:

In order to upload your data to the web you will use the ThingSpeak platform and create your own publishing and sharing channel, with the following steps:

1. **Sign Up**:
   - Visit ThingSpeak.
   - Click **"Sign Up"** and fill out the required details.
   - Verify your email to activate the account.
2. **Create a New Channel**:
   - Log in to your account.
   - Click **"Channels"** > **"My Channels"** > **"New Channel"**.
   - Fill in the channel details (e.g., Name, Description, Fields, Location).
   - Click **"Save Channel"**.
3. **Make the Channel Public**:
   - Open your channel settings by clicking its name.
   - Go to **"Sharing"**.

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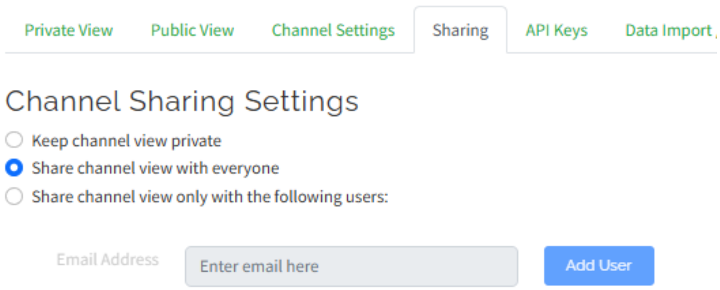
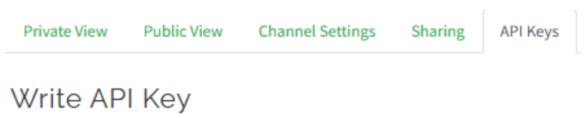
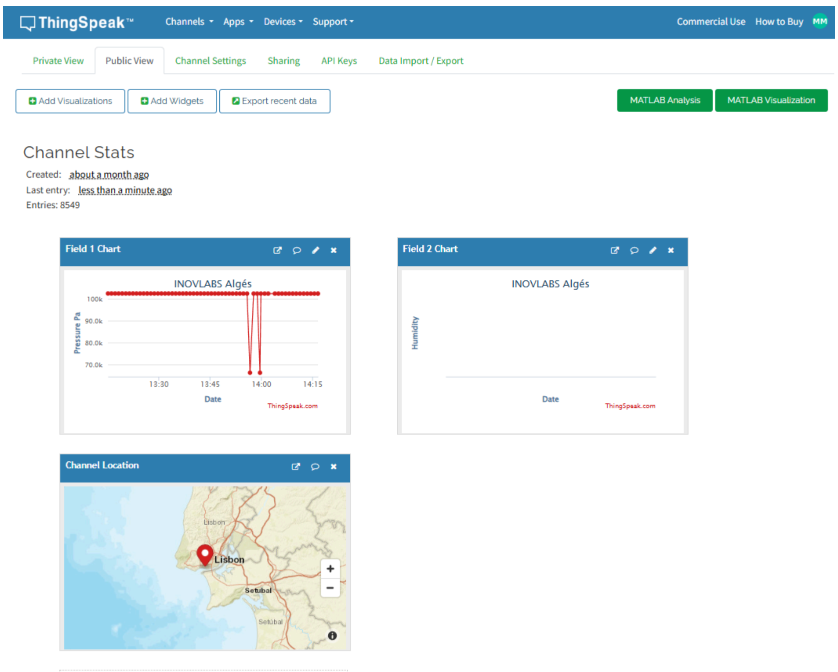
- Select **"Make Public"** and save changes.



4. **Copy the Write API Key**:
   - In your channel, go to **"API Keys"** tab.
   - Locate the **"Write API Key"** and copy it and save it for later (see next step).





Thingspeak channel interface

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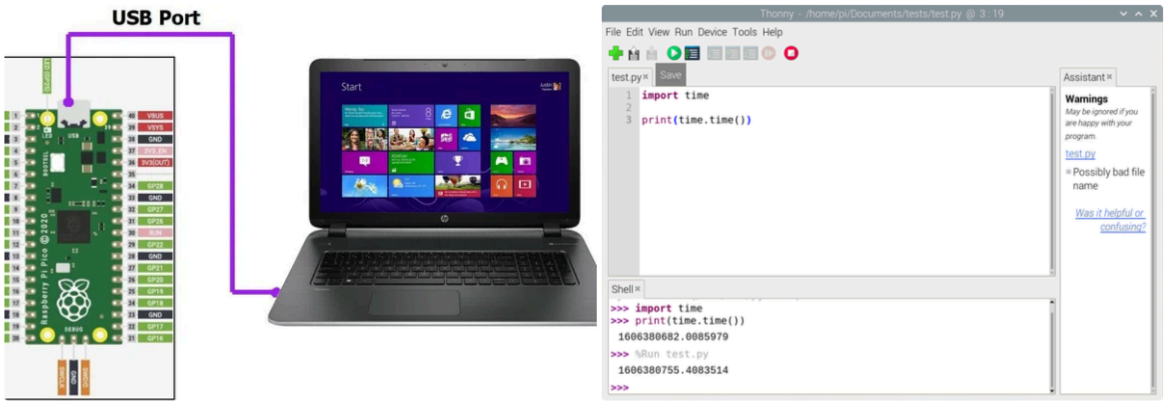

4) Prepare The Rpi Pico W:

The microcontroller is like a small computer that runs a single set of instructions (code). In order to upload the code it has to be configured. It seems a tricky task but just trust and proceed following these steps:

Download the correct MicroPython UF2 file for your board:

Raspberry Pi Pico W with Wi-Fi and Bluetooth LE support

To program your device, follow these steps:

1. Push and hold the BOOTSEL button while connecting your Pico with a USB cable to a computer. Release the BOOTSEL button once your Pico appears as a Mass Storage Device called RPI-RP2.

2. Drag and drop the MicroPython UF2 file onto the RPI-RP2 volume. Your Pico will reboot. You are now running MicroPython.

5) Upload the Code to the Pico

Here are the steps needed to upload the code to run on the microcontroller:

- Download and install Thonny IDE from https://thonny.org/

- Download the Weather Station code from Github:

  https://github.com/vjx/PicoW-WetherStation/archive/refs/heads/main.zip

- Edit the file iot_credentials.py, and insert your own credentials:
  - Change the **THINGSPEAK_WRITE_API_KEY;**
  - Change the ***ssid;***
  - Change the ***password;***

- Upload the following files to the PicoW using Thonny:
  bmp280.py
  tm1637.py

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main.py
Iot_credentials.py (with edited credentials)

A note on the Sonification

The code we prepared and proposed for this project performs a linear mapping of the atmospheric pressure onto the pitch of a particular web sound generator (part of the library Tone.js). Atmospheric pressure typically falls between 950 and 1050 millibars (mb) and we map this interval onto a range of sound frequencies from 200-2000Hz.

We programmed the sound output on the website as a linear mapping but in the class the students could experiment with different types of mapping physical data (like light intensity, temperature or other sensor data) onto pitch with different intervals. As explained in the wiki for real-time and "a posteriori" sonification methods.

6) Assemble The Case

As an optional activity, we suggest building a 3D case to contain our weather station device. Here are the steps to follow:

Download the SVG file from Github
https://github.com/vjx/PicoW-WetherStation/archive/refs/heads/main.zip

Cut the Acrylic Glass using the Top and bottom SVG provided.

Optionally you can print with the case with a 3d printer using the STL files.

Use the Screws and nuts to secure the circuit on the case and close the case.

Alternatively, you can design and build your own case that may include more sensors.

RESULTS OF THE CREATE PHASE:

By the end of your implementation, you can add here results from this phase, including pictures, aha moments, quotes from students and other people involved, etc. This can inspire others to design projects as amazing as yours. You can include here pictures from their creations too.

SHARE

The final step to accomplish our project consists in the sharing of the data. The more interesting the project gets, the more participants we have. For a good sharing practice all the activities should be documented with descriptive videos and shared on the SoundScapes community platform.

5. **Share Thingspeak channel with administrators**
   Send an email to fmedeiros@inovlabs.com with the address of your Thingspeak channel so we can add it to the website.

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The final product consists of a website where anybody can listen to the sonified data of different weather stations. The class should now share it with the educational community, including tutors, and whoever could be interested in the collaborative project of comparing atmospheric pressure localized.

The class must send an email to the administrators of the site **educa@inovlabs.com** with these characteristics:

- subject NEW WEATHER STATION
- name of their weather station
- GPS coordinates
- write API KEY.

With this information a new item will show up in the website and its sound will play in the chorus of the sonified weather stations!

<u>RESULTS OF THE SHARE PHASE:</u>

By the end of your implementation, you can add here results from this phase, including pictures, aha moments, quotes from students and other people involved, etc. This can inspire others to design projects as amazing as yours. You can add here pictures of your students sharing their results and write down final considerations.

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