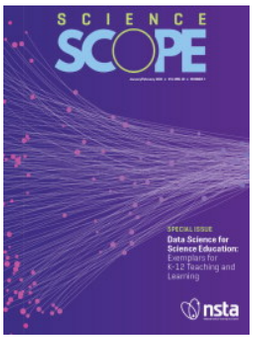

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Adding Sound to Graphs of Data That Change Over Time: A Promising Tool

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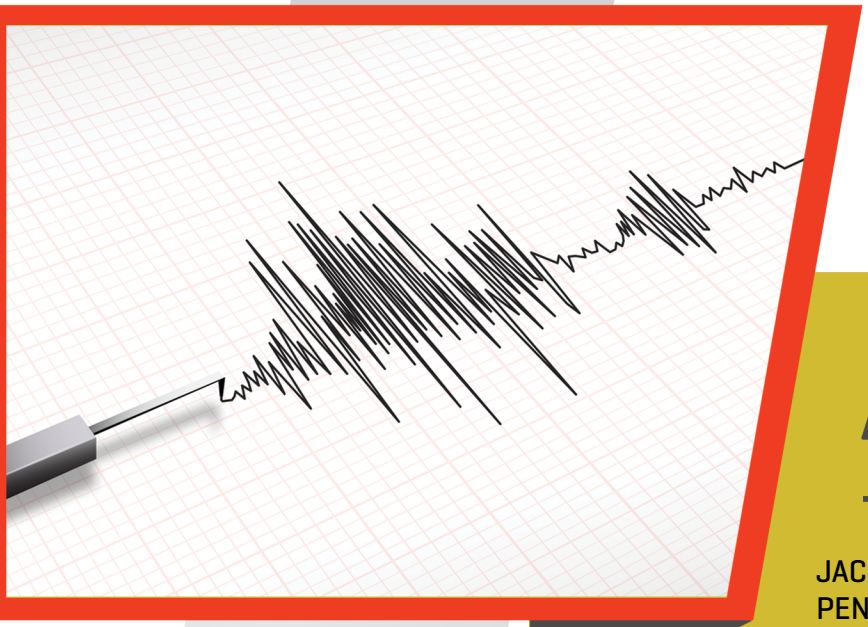
Adding Sound to Graphs of Data that Change Over Time:



A Promising Tool

JACOB SAGRANS, JAN MOKROS, DAN DAMELIN, AND PENDRED NOYCE

ABSTRACT

Learning to construct and make sense of time-series graphs is a key practice in middle school science. We describe a new, free educational tool called "Sonify" that enables students to extend their use of the Common Online Data Analysis Platform (CODAP) so that they can listen to graphs of scientific phenomena that change over time while they simultaneously examine these graphs visually. We report on how listening to graphs helps students attend to key elements, including slope, and how listening might help differentiate instruction. Sonify has special appeal to students who value learning through listening, while at the same time reinforcing understanding of time-series graphs for all students, perhaps especially so for English language learners who may find it easier to relate to the sound of a graph than textual descriptions of it. We describe how students use this new tool and the explanations they give for its appeal.

KEYWORDS: Analyzing and interpreting data; sound; use of technology

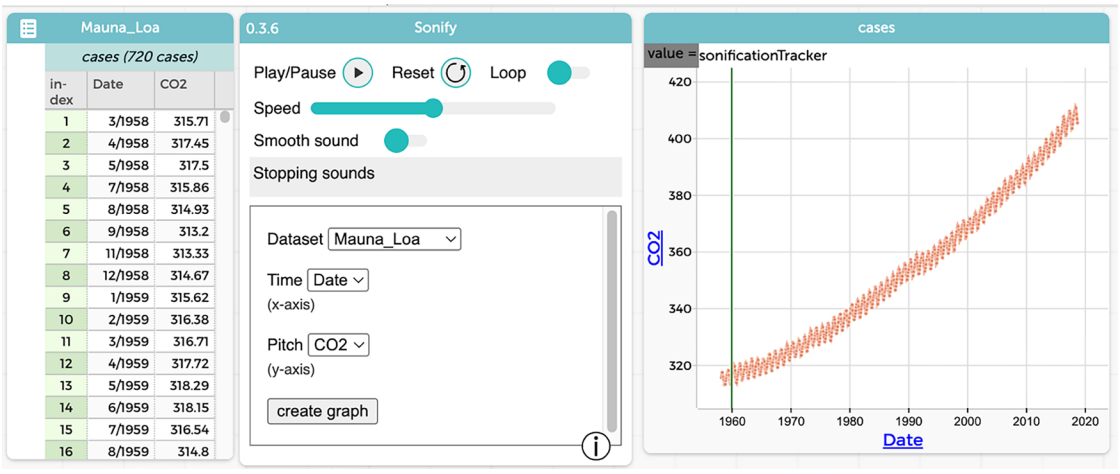
One of the most important and generalizable skills that students learn in middle school science involves constructing, analyzing, and interpreting graphs. Understanding graphs of phenomena that change over time is particularly important, as noted in the *Next Generation Science Standards* (see, for example, LS2.C in MS.Matter and Energy in Organisms and Ecosystems—link in Online Materials) and also in the Pre-K–12 GAISE II Framework for Statistics and Data Science Education (Bargagliotti et al. 2020, 16–17). The *NGSS* also emphasizes that "when possible … students should use digital tools to analyze and interpret data" and includes "Analyzing and Interpreting Data" as a key science and engineering practice (see link in Online Resources to Appendix F: Science and Engineering Practices in the NGSS). A free online educational data tool like the Common Online Data Analysis Platform (CODAP) makes quick work for students wanting to graph data from a table and makes it easy to compare time-series graphs (Concord Consortium 2025). We examine how CODAP's new Sonify plugin enables data sonification where students can pay greater attention to graphs by both hearing and seeing patterns in the data.

Adding sound to a graph

For many years, scientists have been listening to graphs. A familiar and longstanding example is seismographs, in which one listens to seismic activity over time. Scientists ranging from microbiologists to astronomers use data sonification as part of their work, because sound can help them consider multiple dimensions of a phenomenon simultaneously (see, for example: Kim et al. 2020; NASA n.d.). But how does this translate to middle school contexts?

CODAP developers created the new Sonify plugin that adds sound to time-series graphs. Figure 1 shows an example of Sonify being used with a CODAP data set of atmospheric CO_2 concentration measured over a 60-year period. You can follow instructions on how to sonify this data set in Supplemental Materials, and we encourage you to present this data and its sonification to your students. Any time-series data can be played with the Sonify plugin, including data you add to CODAP yourself (see Online Resources for a link to a help page on how to import data into CODAP and also for a link to general CODAP help resources). CODAP's NOAA weather plugin (see link in Online Resources), used in conjunction with the Sonify plugin, would allow you to sonify time-series weather data from any region of the United States. Note that CODAP and all its plugins (including Sonify) are free educational tools with no ads that run in your browser. All you need is a computer of any type (Chromebook, Mac, PC) and an internet connection. A link to a page with an

FIGURE 1: CODAP Sonify plugin screenshot example.



Links to sample data sets to Sonify in CODAP with students

Note that each data set includes a text box of instructions in CODAP on how to sonify it. For additional guidance on how to work with Sonify and how to sonify the data sets listed below, see the sonification tutorial followed by several guided CODAP sonification activities at https://learn.concord.org/cidsee

- Polio infections in Nigeria, 1981 to 2023—*https://bit.ly/4g0iOe4*
- 1918 Flu data for Pittsburgh, PA—*https://bit.ly/4nboSTx*
- High jump Olympic gold medal heights (men vs. women, 1896–2024)—*http://bit.ly/4g1AupE*
- U.S. and Canadian measles cases, 2010 to 2025—*http://bit.ly/3VuBnO2*
- New England Climate data, 1940 to 2024—*http://bit.ly/4n40BwM*
- Daily and total COVID infections in Mexico, spring 2020—*https://bit.ly/3JB0wnM*
- Massachusetts COVID wastewater data, fall 2023—*http://bit.ly/3JFhjGh*

Note that on a graph with two or more series, if only one series is selected, Sonify will only play that series. You can change the selection by clicking on the colors in the legend. If no series are selected, Sonify will play all the series on the graph. To unselect all series, click on a blank area of the graph.

additional tutorial on how to sonify data sets in CODAP as well as several guided CODAP activities involving sonification can be found in Online Resources.

Trials with students

We pilot tested the Sonify plugin as part of our research for a National Science Foundation–funded project that introduced middle school youth to data science through the lens of infectious diseases (NSF 2023). In this broader project, students were often asked to describe the time periods during which infections increased the fastest, stayed steady, or decreased. These were more challenging tasks than simply identifying high or low points on the graph. We hypothesized that adding sound to the graphs would make slope more salient.

We presented sonification to 32 middle school students in total through a focus group, a five-session afterschool program, and three rounds of one-on-one interviews conducted by project staff. These occurred in afterschool programs in two racially diverse urban/suburban schools, as well as in a racially diverse summer camp program with multiple English language learners. We presented sonified data of several types, including:

1. Comparing two groups (e.g., listening to graphs of men's vs. women's winning Olympic high jump heights over the years),
2. Understanding a simple phenomenon with an easy description (e.g., infections went up, then leveled off),
3. Examining a clear trend with some significant variability (e.g., water content in the air over time),
4. Examining a graph with no clear trend (e.g., change in wind speed over time), and
5. Comparing a cumulative graph to a yearly one (e.g., yearly vs. cumulative pertussis/whooping cough infections).

In all these cases, we used sound *along with* the visual graph, because in our first focus group we discovered that sound alone makes little sense to students, perhaps because sound disappears as soon as it is played and it can be hard to remember what you heard. After presenting the visual graph and then playing the graph using the Sonify plugin for each of the different types of data listed previously, we asked students for feedback on the advantages and disadvantages of the sonification tool.

Results

Students readily understood the basic concept of sonification: that higher pitches represent higher values in the data, and lower pitches represent lower values. Some students confused higher pitches with louder volume, but this did not interfere with their overall understanding of the graphs. Students

indicated that sound helped them the most when graphs had many data points. One said: "If [the data points] are close together, you need sound to understand it," adding that sound did not help as much when the data were spread apart, because there were longer silences between data points as the sound played. Sound also helped students differentiate between steep slopes, shallow slopes, and plateaus on the graphs. They noted that a plateau sounds "boring" (one pitch staying the same) and the sound of a steep slope is "dramatic" (a rapid increase in pitch). On a more basic level, many students found it useful to follow the vertical green line that scrolls across the graph while the sonification plays because it showed them exactly where they were in the data as they were hearing it.

An interesting finding was that several students—especially those who were involved in music—both enjoyed and were able to compare the sound of two different data series played at the same time (e.g., playing the sound of a graph with one series showing yearly pertussis cases and another showing cumulative pertussis cases on the same graph). One student said that there was a close analogy between reading/playing musical notation and reading/hearing graphs. He talked about listening to the "harmony" created by playing two lines at the same time but added that sometimes the resulting sound was not very harmonious.

Students reported that they found the sonification tool easy to use and enjoyed being able to control the speed of play. In general, students started by playing a graph at a faster speed but then slowed it down so they could more easily hear what was happening. Sonification engaged students, and they sometimes compared it to listening to certain types of music, such as techno. Students had a clear preference for using both sound and visual graphs together, rather than using visual graphs or sound alone. Students could also adjust the mode of play, so that it either played smoothly ("Smooth sound" mode, with the sound sliding between each data point) or played discrete/separate "beeps" for each data point. Students enjoyed trying out the two modes, although there was not a clear preference for either one.

Implications for educators

Sonification is easy to add whenever you are using CODAP with time-series data, and it is adaptable to different circumstances. Some students may want to listen to the graphs as well as examine them visually. It is easy to differentiate instruction when using Sonify because students can choose how many times they listen, the speed at which they listen, and other parameters, including whether the graphs sound smooth or have a discrete "beep" for each data point on the graph. We recommend that you have students use headphones when listening to the graphs individually on their own computers, or spread out students in small groups, each with one computer playing sound from its speakers.

By increasing the number of ways students can explore a graph, sonification invites students to spend more time examining each graph, which in itself could lead to a deeper understanding of the data. While it is new and more research is needed, the Sonify tool has significant potential to help students learn about time-series data. See the Box for links to some sample data sets to sonify in CODAP. We hope you have fun exploring sonified time-series data with your students! ●

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SUPPLEMENTAL MATERIALS

Instructions on how to sonify a data set in CODAP on atmospheric CO_2 concentration over a 60-year period [the Mauna Loa data set]— http://doi.org/10.1080/08872376.2025.2601359

ONLINE RESOURCES

Tutorial and guided activities on how to sonify different types of data sets in CODAP—*https://learn.concord.org/cidsee*

Help page for how to import data into CODAP—*https://bit.ly/40qrRPv*

General CODAP help resources—*https://codap.concord.org/help/*
Descriptions of CODAP's built-in plugins, including the NOAA weather plugin—*https://bit.ly/3CXKHEK*
MS.Matter and Energy in Organisms and Ecosystems—*https://tinyurl.com/52be5whc*

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Appendix F: Science and engineering practices in the NGSS—*https://tinyurl.com/yfhfd8rw*

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