GENERATIONGENIUS
ALWAYS QUESTION. ALWAYS WONDER.

TEACHER GUIDE

DIGITAL VS. ANALOG SIGNALS
GRADES 6-8

COMMON MISCONCEPTIONS

- **The terms *analog* and *continuous* are synonymous.**
  Although analog signals are continuous, these two terms are not synonyms. Analog signals are called this because they are analogous, or proportionate, to the real-world phenomena they represent. For example, the movement of the hands on an analog clock are proportionate to the passage of time and particularly to the rotation of Earth around its axis.

- **Digital is always better.**
  Although digital signals are more reliable for storing and transmitting information, that does not mean that digital is always preferable to analog. The real world produces analog data and human perception is inherently analog, so analog signals are preferred when we want to capture natural variability or allow our senses to filter naturally noisy data.

- **Digital audio recordings cannot match the quality of analog recordings.**
  Early digital audio recordings were limited by the quality of equipment used to encode and decode the signals and by data storage capacity. Because both of these have improved, we can now sample analog audio at such a high rate that humans are not able to detect the difference between high-quality analog and digital recordings.

THE IMPORTANCE OF SIGNALS AND INFORMATION

Information is essential to our lives. We are constantly taking in, making sense of, and responding to information in our environment in the forms of sights, sounds, feelings, and other perceptions. In a broad sense, a signal is anything that conveys information. So a smile and a text message are both examples of signals. In the context of electronic technology, a signal is a value, like voltage or current, that varies over time in a way that conveys information. Anytime we think about signals, we also need to think about noise. In this context, noise is anything that detracts from the useful information carried by a signal. When you are trying to hear a friend who is calling to you across a room, all the other sounds in the room become noise.

LIVING IN AN ANALOG WORLD

Visible light occurs along a continuous spectrum of wavelengths from 380 to 700 nanometers, and our eyes can detect about 1 million distinct colors. Our ears can hear sounds at any frequency between 20 Hertz and 20,000 Hertz.

Temperatures can take any value along a scale, falling between 0°C and 100°C in most of our daily experiences. Atmospheric pressure, precipitation, levels of carbon dioxide in the atmosphere—the list goes on and on. Variables in the real world are generally continuous variables; they can take on any value within a certain range. When we capture these variables as electronic inputs, we are dealing with analog signals. The word *analog* comes from a Greek root meaning *proportionate*, and we can think of analog signals being proportionate to the real-world value they are measuring. As an example, the continuous movement of gears in an analog clock is proportionate to the continuous passage of time and the continuous rotation of Earth around its axis. So the world around us is analog, but the computers that play increasingly important roles in our everyday lives are digital.

GOING DIGITAL

Computers range from the controllers in devices as simple as digital alarm clocks to the smartphones many of us carry to the large mainframes that process millions of financial transactions each day. At the most fundamental level, every computer is controlled by a series of instructions composed of only two digits, with 0 representing "off" and 1 representing "on." As a result, all of those analog signals from the real world must be converted into digital signals in order for computers to work with that information. This conversion is accomplished by taking samples of the continuous analog signal at regular time intervals and encoding the value of that sample in digital form. If you think of the smooth analog curve of a sound wave viewed on an oscilloscope, the digital version of that wave would have a similar shape but would be composed of a series of small stairsteps. Converting analog signals to digital form has advantages beyond just allowing computers to handle the information. Signals that are stored and transmitted in digital form are more reliable because they can be easily corrected to eliminate noise, interference, or signal degradation.

TEACHER TIPS

- Focus on activating prior knowledge and encouraging student questions from the phenomena videos to motivate the signal transmission simulation. The simulation is most authentic if it is generated by student questions.
- Facilitate student discourse among each other and publicly with the class to support consensus-building. It is important for the class to take stock in competing ideas and then use evidence to figure out science ideas. Help the class arrive at an evidence-based conclusion rather than presenting the core idea as received knowledge.
- If students have trouble distinguishing between the terms *analog* and *digital*, emphasize that digital signals use digits, like 1s and 0s, to code for information, whereas analog signals are analogous, or similar, to the information. So the bumps in the groove of a record actually mimic the vibrations of the sounds recorded on the record, whereas the pits and bumps on the reflective surface of a CD represent 1s and 0s that code for information that can be used to recreate sound waves.

ABOUT THIS LESSON

This lesson was created by the National Science Teaching Association (NSTA) to pair with the Generation Genius video and support *NGSS*.

They have requested we provide the following background with this lesson:

The Next Generation Science Standards (NGSS) are the national standards on how students learn science, and they are based on contemporary research presented in *A Framework for K–12 Science Education (the Framework).* The shift in science teaching and learning required by the Framework is summarized in this infographic: A New Vision for Science Education.

At the start of each Generation Genius lesson, students are presented with a phenomenon, then they try to explain it. Students will notice they have gaps in their knowledge and ask questions, which motivates them to build ownership of science ideas they need in order to explain how or why the phenomenon occurred. The way students build ownership of science and engineering ideas is through active engagement in the science and engineering practices (SEPs). This process of sensemaking, or doing science to figure out how the world works, is one of the major shifts the *Framework* encourages.

To engage in the SEPs, students should be part of a learning community that allows them to share their ideas, evaluate competing ideas, give and receive critiques, and reach consensus. Students can start by sharing ideas with a partner, then with a small group, and finally, with the whole class. This strategy creates opportunities for all students to be heard, build confidence, and have something to contribute to whole-class discussions. Each Generation Genius lesson provides conversational supports to facilitate such productive student discussions to contribute to sensemaking.

Excited to continue your shift toward the new vision for science education? Check out the Generation Genius Teacher Guide page on the NSTA website for resources and strategies to engage every student in your classroom in **doing** science.