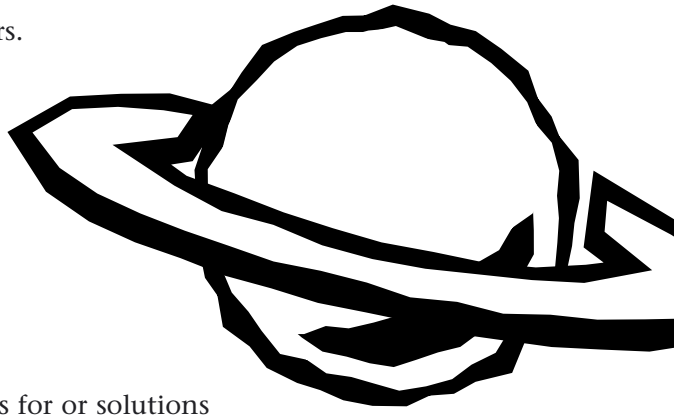
CLASSROOM ACTIVITY

Decoding an Extraterrestrial Message

General information



★ Level: elementary cycle three and secondary I to V.

★ Students per group: individual activity or in pairs.

★ How long: 30 minutes.

★ Where: classroom.

★ When: before or after visiting the Montréal Planetarium.

★ Type of activity: discovery.

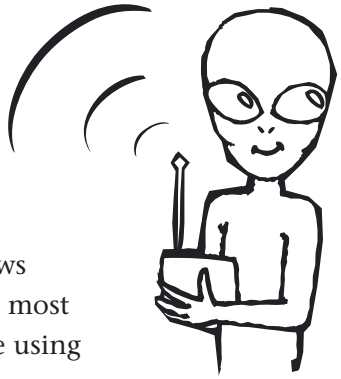
★ Subjects covered: science, technology, math.

★ Disciplinary competencies: propose explanations for or solutions to scientific or technological problems; apply scientific or technological knowledge; communicate in the languages used in science and technology; communicate in the language of math.

★ Cross-curricular competencies: make use of information; solve problems; exercise critical judgment; apply creative thinking; communicate appropriately; adopt effective work methods.

Starting point

Imagine you've just picked up a signal from outer space made up of a series of zeroes and ones. Could you decode this message from the stars? Would you understand what it meant?



Preconceptions

Science fiction, especially in the movies and on television, often shows extraterrestrials speaking fluent English. If extraterrestrials exist, they most certainly don't speak our language. They may not even communicate using a spoken language.

Basic concepts

Just as there's a language barrier between different human civilizations sharing this planet, there'll no doubt be an even greater language barrier between humans and any extraterrestrial civilization we're able to contact (if, of course, such civilizations exist).

Odds are, however, that if these extraterrestrials use advanced technology such as telecommunications and space travel, they'll have already developed a mathematical language, which is more universal. For example, the value of pi (the ratio of the circumference of a circle to its diameter) is the same throughout the Universe. Basic mathematical operations (addition, subtraction and such) will give the same results everywhere. In short, mathematics could become a sort of cosmic Esperanto enabling dialogue between civilizations, or at least a way to establish first contact before we create human-extraterrestrial dictionaries. Certainly the day when we pick up a message from outer space, we'll need to call on our best mathematicians to decode it and try to understand its meaning.

What's the best way to communicate with an extraterrestrial civilization dozens or hundreds of light-years away? Exchanging messages using radio waves has many advantages. Although the intensity of the signal produced decreases with the square of the distance, the waves move at the speed of light and undergo very little interference or weakening despite travelling thousands of years. Also, producing waves powerful enough to journey straight across our galaxy costs practically nothing, and we already have the technical capacity. For a more advanced civilization, this would be even easier!

To sum up, here are the main points about messages from extraterrestrials:

- First contact with an extraterrestrial civilization will be by radio waves.
- Extraterrestrials will not speak any language spoken on Earth.
- A message from an extraterrestrial civilization will be difficult to interpret.
- Mathematics and the laws of physics are the same throughout the Universe regardless of the "cultural differences" among civilizations living in it.

- An extraterrestrial civilization will perhaps want to use simple mathematical concepts, such as prime numbers, to convey a message.
- A prime number is a number divisible only by itself and 1 (examples are 1, 2, 3, 5, 7, 11, 13, 17, 19 and so on).
- A message from an extraterrestrial civilization may be in the form of a simple image.

Goals

By the end of this activity, students will be able to:

- Transpose a message made up of zeroes and ones onto a grid.
- Interpret the image constructed.
- Create "messages" made up of zeroes and ones in order to transmit the information to other students.

Steps in the activity

Preparations

Make one copy of the handout "Decoding an Extraterrestrial Message" for every student.

Supplies

- A copy of the handout "Decoding an Extraterrestrial Message."
- Pencils

Assignment

❶ Tell students they'll see the transcription of a message recently picked up by a radio telescope at the Dominion Radio Astrophysical Observatory in Penticton, British Columbia, at a frequency of 1420 MHz. The message comes from extraterrestrials. What will the message look like? Will we be able to decode it? To understand it? To answer these questions, your students will try to decode and understand this message from the stars.

❷ Pass around the handout. Point out that the message is made up of two symbols: zeroes and ones. Do we know any machines that use only two symbols to process data and communicate to each other? Fax machines and computers, of course! These machines use only zeroes and ones to exchange information.

❸ Ask students to count the number of zeroes and ones in the message. The message consists of 22 zeroes and 13 ones (hence, 35 "bits" of information in total). How is the number 35 special? It's not a prime number, but its divisors are (35 can be divided only by itself and the primes 1, 5 and 7). This suggests a way to "organize" the information. Students may obtain good results if they lay out the zeroes and ones on a grid containing five rows and seven columns, or seven rows and five columns.

We already use a similar technique to transmit black-and-white images by fax or satellite. The images are first "broken down" into a very tight grid. Each of the squares is represented by a one or a zero, depending on whether it is black or white. This produces a long series of zeroes and ones that the receiving fax reorganizes to recreate the image. Is this technique what extraterrestrials hope to see us use?

❹ To clarify this notion, ask students to place the zeroes and ones on a 5 x 7 or 7 x 5 grid. You can divide the group into two, the first group using the first grid (five rows and seven columns) and the second group using the second grid (seven rows and five columns). You can also have each student complete the two grids.

Students must transcribe the message line by line. They begin in the top left corner and move right, darkening the squares representing a one and leaving blank the squares representing a zero. They then move to the front of the second row and continue. So that they don't forget a zero or one (which would completely ruin the message), suggest that they check off the "bits" of the message as they move each bit to the grid. Give them a few minutes to complete this exercise after making sure they've all understood the procedure.

Wrap-up

When everyone has finished, ask the following questions. Which of the two patterns (Grid 1 or 2) is more meaningful to them? Why? Do they recognize the symbol created on Grid 2? The pattern resembles the astronomical symbol for the Sun, but it's unlikely that extraterrestrials know this symbol. Instead, the message probably represents a circle and its centre, which would be an invitation to converse about the mathematical properties of the circle. The aim would be to build an initial lexicon of their language and ours based on a few simple mathematical concepts.

Mention the message sent in 1974 by the Arecibo radio telescope (see Appendix 1).
If extraterrestrials receive this message one day and analyze it in the way we've just done, they may be able to understand what the contents of this message mean.

But even if they aren't able, at least they'll realize they aren't alone in the Universe. Indeed, the main goal of the research program at SETI (Search for Extraterrestrial Intelligence) is not to decode and understand the contents of a message from outer space. We may never be able. But if we do pick up such a signal, we'll at least know we aren't alone in this vast Universe of ours.

Extra credit

Students draw a simple geometric figure (such as the letters Y or Z or a stylized human figure) on graph paper within a grid 5 x 7 or 7 x 5. They then transcribe the figure in a series of zeroes and ones (0 being a blank square and 1 a dark square). Finally, they "transmit" their message to another student or team, who must decode it to discover the hidden meaning.

Adapted from Decoding an Extraterrestrial Message, developed by Dr. Roberta Vaile of the SETI Institute in California.

APPENDIX 1

The Arecibo message

In 1974, a team of U.S. radio astronomers designed a message that they beamed out to the globular star cluster M13 in the constellation Hercules using the large Arecibo radio telescope located in Puerto Rico.

The message consisted of 1,679 bits of information, essentially zeroes and ones.

The number 1,679 is divisible only by itself, 1 and the primes 23 and 73. By transposing these bits onto a grid of 73 rows and 23 columns, we create a visual message that contains a wealth of information enabling a possible recipient to discover who we are.

The message begins with a representation of the numbers 1 to 10 written in binary mode (zeroes and ones) and read from right to left. Next come the atomic numbers of the most common elements in the chemistry of life: hydrogen, carbon, nitrogen, oxygen and phosphorus. These numbers are followed by a representation of the chemical formulas of the 12 amino acids on which human biology is based.

In the centre of the message is a stylized figure representing the DNA double helix with, in the middle, the number 4 billion in binary mode (representing the number of nucleotide pairs in each of our chromosomes). Further down, a human figure is flanked on the left by the number 4 billion (the population of Earth in 1974) and on the right by the number 14 (representing the average human height expressed in units of the wavelength of the transmission). The number 14 multiplied by 12.6 cm (the wavelength of the radio signal transporting the message) equals an average height of 1.76 m.

Just under the human figure lies the Earth in a depiction of the solar system. Here, the relative size of the Sun and planets (running from right to left) is demonstrated by the length and thickness of the figures. The message ends with an illustration of the Arecibo radio telescope used to send the message. This gives clues about our level of technological development. The telescope's diameter (300 m) is also expressed in units of the wavelength of the signal used to transmit the message.

The globular cluster M13, which the message was sent toward, is a grouping of hundreds of thousands of stars located 21,000 light-years from Earth. This means that by travelling at the speed of light, the message will take 21,000 years to cover the distance that separates us from the cluster. If ever the message is picked up, decoded and understood and an extraterrestrial civilization wishes to respond, it'll take another 21,000 years for this response to reach the Earth.

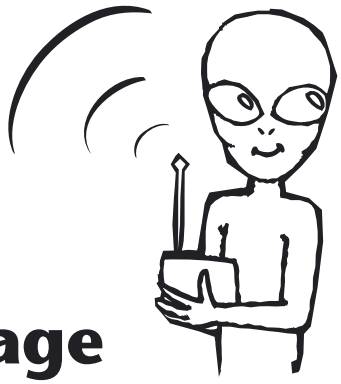
As its creators freely admit, the aim of the operation wasn't to establish dialogue between civilizations. Rather, the goal was to show the feasibility of sending a coded message to the stars in order to persuade financial backers to fund SETI (Search for Extraterrestrial Intelligence). The SETI project entails pointing powerful radio telescopes skyward to try to pick up a radio signal of extraterrestrial origin. The project, which was launched in the sixties, has yet to detect any intelligent signal from space. Yet the search continues.

For more details, drop by:

http://www.seti.org/

http://astrobiology.arc.nasa.gov/

STUDENT HANDOUT



Decoding an Extraterrestrial Message

Radio astronomers from the Université de Montréal have recently picked up a signal from the stars using a radio telescope from the Dominion Radio Astrophysical Observatory in Penticton, British Columbia. The researchers believe that the signal is a binary message sent by an extraterrestrial civilization.

Here's the content of the message: 0 0 1 1 1 0 0 0 1 0 0 0 1 0 0 1 0 1 0 1 0 0 1 0 0 0 1 0 0 0 1 1 1 0 0

- How many zeroes are in the message? _____
- How many ones are in the message? _____
- How many bits of information in total are in the message? _____
  (A bit of information is a zero or a one.)
- Which two prime numbers (other than 1) can you divide this total number of bits by?

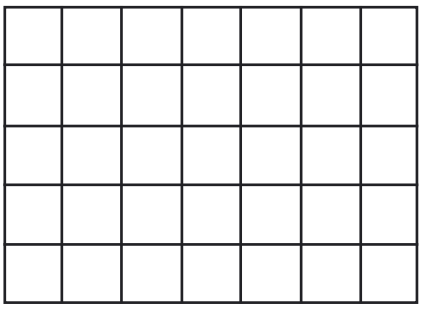
_____

To understand the message, astronomers suggest transposing the zeroes and ones onto a grid with the number of rows and columns matching the two prime numbers you've identified in the question above. Darken the squares representing a one and leave blank the squares representing a zero.

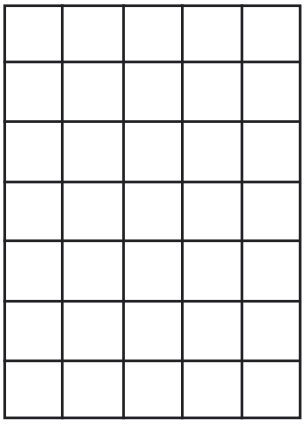
Hint: Fill in the squares beginning with the top left corner of the grid and continue to the end of the first row. Then jump to the next row and do the same. To avoid errors, check off each bit in the message as you transpose it onto your grid.

Good luck!

Grid n° 1



Grid n° 2



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