OVERVIEW

Description:
Guide students through explorations related to the concept of coding using binary code.

Standards Met:

**NGSS 4-PS4-3:**
Generate and compare multiple solutions that use patterns to transfer information.

**CCSS.Math.Content.6.EE.A.1:**
Write and evaluate numerical expressions involving whole-number exponents.

**CSTA K-12 5.2 Level 2 CT 14:**
Examine connections between elements of mathematics and computer science including binary numbers, logic, sets and functions.

**CSTA K-12 5.3.B CT 7:**
Discuss the interpretation of binary sequences in a variety of forms (e.g., instructions, numbers, text, sound, image).

PREPARATION

Ages/Grades: 7th - 12th

Objective(s) covered:
- Encode messages from English using binary codes
- Decode messages from binary into English using decoding tables and code trees
- Interpret binary codes using code trees
- Use code trees to create binary codes

Materials:
- Pencil/paper
- paper clips (large and small)
- web browser
- [Word Finder website](optional, for message ideas)
- [Huffman Coding](optional, information on binary code trees)
- [Letter frequency](optional, resource to see how frequently letters occur in the English language)
- Graphical software like [Lucidchart](optional)

Time needed: 45-60min
ACTIVITY DESCRIPTION

Opening:

Characters in Interstellar use binary codes to transmit and receive messages. Our world today is filled with binary transmissions created and processed by computers. This lesson will help students begin to understand how binary sequences can be used to communicate information between machines and people. Students will be given the opportunity to use binary code to send and receive messages with their peers.

Activity:

Part 1: Decoding messages using a binary tree.

Begin by asking students if they have ever heard of the numerical system used by computers to process information. Many students will probably be able to answer “ones and zeros”, while others may be able to use the term “binary”. A binary system consists of only two digits, 1 and 0. All information on a computer system has been translated into binary representations. Explain the use of the binary tree shown above using by describing the following steps.

1. Start decoding binary messages (sequences of 1s and 0s) by locating the START of the tree.
2. As you read a binary message, trace a path on the tree corresponding to the sequence of digits read. Move down and left one segment if you read a 0, and move down and right one segment if you read a 1.
3. When arriving at a location that has a letter, record the letter and return to the START of the tree using the next digit in the binary sequence.
4. Repeat steps 2, 3 and 4 until all binary digits in your message have been used.
Activity Continued: For example,

\[0 \ 1 \ 0 \ 0 \ 1 \ 0 \ 0 \ 1 \ 0 \ 1 \ 0 \ 1 \ 1 \ 0\]

can be translated into

S       T        A           R

and

\[0 \ 0 \ 0 \ 1 \ 1 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 1 \ 1 \ 1\]

can be translated into

K        I            N          D

Note that while both translated message have four letters, the sequences of 1s and 0s have different lengths. Letters that are more commonly used have shorter binary representations than letters that are less commonly used. This allows for greater efficiency for storage and transmission.

Ask students to translate the following binary sequences. Include sequences that you want them to consider as well.

\[0 \ 1 \ 0 \ 0 \ 1 \ 0 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 1 \ 1 \ 1\] binary sequence to be translated

S       A           N          D (answer)

\[1 \ 0 \ 0 \ 0 \ 1 \ 1 \ 0 \ 1 \ 0 \ 1 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1\] binary sequence to be translated

T          R        A        I           N (answer)

Note: Some letters of the alphabet have not been included. A complete tree representing the entire alphabet can be created, but it would increase the complexity beyond what may be appropriate for introductory students.

Have students work in pairs and help each other check their work. (10 minutes depending on the number of sequences given).

Part 2: Encoding messages using a binary tree.

Ask students to examine the list of letters that appear on the binary code tree and generate words using only those letters. Indicate that they may use the same letter more than once in a word. If web access is available, students can use online resources to generate words for letter lists. Have students encode their words into binary form by following the steps outlined below.

1. Find the first letter in your chosen word on the binary code tree.
2. Trace the path from START to the chosen letter, recording in order the sequence of 1s and 0s associated with the trace.
3. Select the next letter in the chosen word and repeat steps 2 and 3, adding the new 1s and 0s from the next letter to the previously generated sequence until all letters have been translated into binary.

Have students work in pairs and help each other check their work. (15 minutes depending on the number of sequences generated).
Activity Continued: Part 3: Sending messages.

*Interstellar* included a scenario in which one character had to communicate with another character using binary code. Have students create a coded message that begins with English letters and is translated into binary form. Have students

1. Choose the message to be sent.
2. Translate the message into binary form using a coding tree.
3. Create a sequence of large (1) and small (0) paper clips linked together in order that represents the binary sequence from part 2.
4. Send the linked paper clips to their peers and have the peers translate the binary message represented by the paper clips into English letters.

(25 minutes depending on the length and complexity of the messages)

Closing/assessment: As an extension to this lesson, students could learn to create binary coding trees that efficiently represent given letters and usage frequencies as binary sequences that are as efficient as possible.
**ADDITIONAL RESOURCES FROM**

Google Play for Education is a content store built just for schools, making it easy for teachers to find and share educator-approved apps, books, and videos with their students.

If your school is using managed Chromebooks or Android tablets, you can use Google Play for Education to distribute the following apps, books, and videos, and take the lesson further.

<table>
<thead>
<tr>
<th>App/Book/Video:</th>
<th>Lucidchart [Chrome App]</th>
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<tbody>
<tr>
<td>Description:</td>
<td>A web-based diagramming tool that makes drawing diagrams fast and easy</td>
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<tr>
<th>App/Book/Video:</th>
<th>Binary Numbers</th>
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<tbody>
<tr>
<td>Description:</td>
<td>An introduction to binary numbers from Khan Academy</td>
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<tr>
<th>App/Book/Video:</th>
<th>Collins Lab: Binary &amp; Hex</th>
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<tr>
<td>Description:</td>
<td>Decimal isn't the only way to represent a value - get acquainted with Binary &amp; Hexadecimal, two very important numeral systems often found lurking within the depths of technology.</td>
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<th>App/Book/Video:</th>
<th>An Introduction to Information Theory: Symbols, Signals and Noise</th>
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<td>Description:</td>
<td>Learn about encoding and binary digits, entropy, language and meaning, efficient encoding, and the noisy channel, then explore the ways in which information theory relates to physics, cybernetics, psychology, and art.</td>
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