Cryptography:
Binary Counter

This activity will introduce binary counting, the difference between base-ten and base-two systems, and the reason binary is used in computing. You will create a paper tool that will help you convert numbers to binary.

Grade Level(s)
4-8

Approximate Time Required
1 hour

Materials
- Colored pencils
- Paper
- Scissors
- Binary counter template printout (optional)
- Computer with internet access for research

NOTE: See note about intenet safety below.

Activity Notes:
- Using an online search engine to conduct your own research is a great learning experience but should be done with constant adult monitoring. You should be informed in advance what to do if you encounter content that is not appropriate. It is suggested that a family friendly search engine like https://www.kidtopia.info/ or https://www.kiddle.co/ be used.

Introduction

Have you ever heard someone say that computers or programming is just a bunch of ones and zeros? What does that mean? How can a computer operate using only ones and zeros? The answer begins with understanding two systems of numbering.

When you count, you use the numbers zero through nine (0-9) and these numbers repeat each time a new place value digit is added. (0, 1, 2, 3,… 8, 9, **1**0, **1**1, **1**2, **1**3,… **1**8, **1**9, **2**0, **2**1, **2**2, **2**3,…)

Each time you pass 9, the next place value moves up one. For example, when you reach 99, a one is added to the hundreds place and the tens and ones place reset to 0 and it starts all over until the tens place reaches nine. Then one more is added to the hundreds place (… **9**8, **9**9, **1**00, **1**01, **1**02,…**1**98, **1**99, **2**00,…). The pattern continues as you keep counting. This way of writing or representing an amount is called a base-10 system because it relies on a set of ten repeating digits 0-9. Yes, zero is a number and extremely important to both the base-10 system and computing.

One way of picturing this is to think of all the place values at once. This is how the number 79 would appear.

Ten Thousands	Thousands	Hundreds	Tens	Ones
			7	9

Is every space used?

Now look at the chart below. How is this number different from the previous one?

Ten Thousands	Thousands	Hundreds	Tens	Ones
0	0	0	7	9

Typically, you only write the place values that are being used. It is understood that there is no need to represent every place value when writing a number.

The digits zero through nine represent a range of values or amounts and this creates a problem when dealing with computers. Computers have trouble with the range of values because of electricity. In order to give a number such as 5, and have that number represent something specific that the computer would understand, you would have to regulate the amount of electricity coming into the computer to a specific current level every time a 5 is represented. This would bring you into the realm of quantum computing and simply isn't practical right now.

A more efficient and simpler method is needed to represent numbers. Instead of regulating the amount of electricity coming in, what if the computer detected whether there is a current at all? You could assign a specific place for current to go and determine if that space is either "on" or "off." Then represent that place with either a 1 or a 0. This system of numbering is called a base-2 system or binary. Binary is a system which represents data using a two-symbol system. In this case, a one or a zero.

Just like base-10, there are patterns in the system. Look at the list of numbers. Do you recognize any patterns in the numbers? *Hint*: these numbers are listed in order from least to greatest.

1
10
11
100
101
110
111
1000
1001
1010

Now reexamine the list of numbers but think of them as the numbers one through ten. Does this change your thoughts about the list? In your Learning Journal, copy the list of numbers, write the base-10 numbers beside each one, and list questions you have after you have analyzed the list.

Activity 1: Counting in Binary

Examine the table below. What do you observe?

128	64	32	16	8	4	2	1

The place value ends at 128 but this is only for this activity. In reality, binary continues infinitely just like base-10 numbers. To use this system, you must begin with a number that you want to represent. You then work your way left to right and ask yourself, "Is my number greater or equal to ______?"

For example, If you want to write the number 0, you would simply write a 0 in the last place under the one, same as in base-10. How would you represent the number 1? Working your way left to right, you can ask yourself…

- Is my number greater than or equal to 128? - No
- Is my number greater than or equal to 64? - No
- Is my number greater than or equal to 32? - No
- Is my number greater than or equal to 16? - No
- Is my number greater than or equal to 8? - No
- Is my number greater than or equal to 4? - No
- Is my number greater than or equal to 2? - No
- Is my number greater than or equal to 1? - YES

Since you can only use one and zeros, each YES would be written as a 1 and each NO written as a 0. Unlike base-10, you should represent each place value with a digit. Therefore, 1 would be written as 00000001.

128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	1

What about a larger number such as 56? Again, you would work your way through the questions.

- Is my number greater than or equal to 128? - No
- Is my number greater than or equal to 64? - No
- Is my number greater than or equal to 32? - Yes

For each YES, **subtract** that amount **and continue** with the difference (56 - 32 = 24). Now continue with 24.

- Is my number greater than or equal to 16? - Yes
  - 24 - 16 = 8
- Is my number greater than or equal to 8? - Yes
  - 8 - 8 = 0
- Is my number greater than or equal to 4? - No
- Is my number greater than or equal to 2? - No
- Is my number greater than or equal to 1? - No

128	64	32	16	8	4	2	1
0	**0**	**1**	**1**	**1**	**0**	**0**	**0**
		56-32=24	24-16=8	8-8=0			

Looking back through the answers, **56** would be written as **00111000**.

What about these numbers? Convert the following numbers from base-10 to binary.

27

128	64	32	16	8	4	2	1

100

128	64	32	16	8	4	2	1

85

128	64	32	16	8	4	2	1

Think: Do you notice any patterns between the even and odd numbers when they are converted to binary (56, 27, 100, 85)?

Activity 2: Paper Binary Counter

You will need the following materials:

- Colored pencils
- Paper / Cardstock
- Scissors
- Binary Counter Template (optional)

You can create a foldable to help you convert base-10 numbers to binary.

1. Fold a sheet of paper in half lengthwise.
2. Place the folded paper landscape oriented in front of you.
3. Fold the top flap in half so that the bottom of the flap touches the crease of the page (Fig. A).
4. Cut seven equally spaced lines across the half page so there are eight individual flaps. Stop the cut at the crease.
    - Tip: make the first cut at the halfway point of the section. Then cut the two pieces in half then those pieces in half to make the cuts even.
5. Label the outside of each flap with a zero (Fig. B).
6. On the inside, label each flap with a number in the following order left to right, 128, 64, 32, 16, 8, 4, 2, 1 (Fig. C).
7. Under each flap on the uncut paper, write a number one (Fig. D).

Fig. A

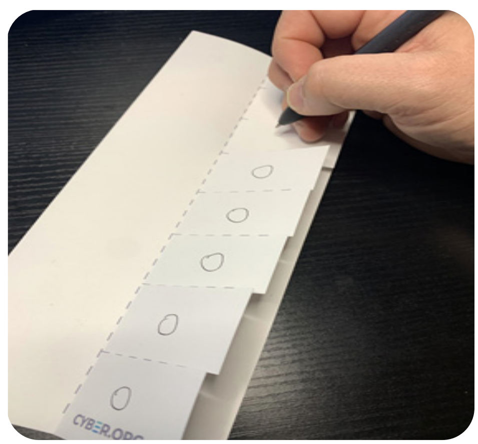

Fig. B

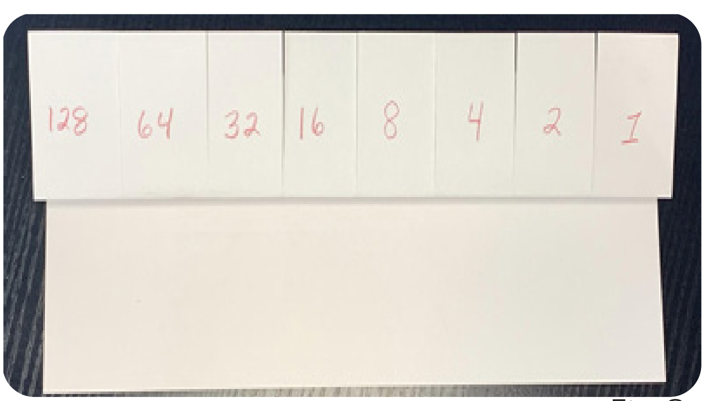

Fig. C

Fig. D

Binary Counter

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