Lesson Plan:
Binary Bracelets
Adapted for QuanTime NM

LEARNING OBJECTIVES

At the end of the 40-minute period, the students should be able to:

1. Explain that information can be stored in binary digits.
2. Convert basic information (letters) to binary.
3. Describe how binary is used in computing.
4. Relate binary to quantum computing.

BACKGROUND INFO FOR TEACHERS (teacher notes)

Focus: Binary

For this activity, the teacher will introduce the binary numbering system and students will convert letters into binary and create secret messages using binary.

Decimal vs Binary Numbering System

In computing, information is stored in bits as 0's and 1's via the binary numbering system. We are typically taught how to count using the decimal numbering system, in which the digits from right to left represent 10^0, 10^1, 10^2, etc. In the binary numbering system, the digits from right to left represent 2^0, 2^1, 2^2, etc. Using this system, we can convert decimal numbers, text, sound, and images to 0's and 1's for computing purposes.

Tie to Quantum Computing

Quantum computers use quantum bits called "qubits" (typically very tiny things like atoms or electrons or photons). Our qubits can also represent a 0 or 1, but they also have a special "superposition" state that is a combination of both 0 and 1. It's important to understand binary for quantum computing.

Notes

Superposition is when a particle exists in a combination of two states.

Watch a video:
https://www.khanacademy.org/computing/code-org/computers-and-the-internet/how-computers-work/v/khan-academy-and-codeorg-binary-data

CONNECTIONS TO COMPUTER SCIENCE STANDARDS

2-DA-07	Represent data using multiple encoding schemes
3A-DA-09	Translate between different bit representations of real-world phenomena, such as characters, numbers, and images.

PROCEDURE

Preparation

- Understand Teacher's Notes.

Materials

- Teacher's Notes/Lesson
- Printed and cut Binary Bracelet Worksheet
- Tape
- Beads and string (optional)



Time: 40 min
Middle School – High School

Step 1: (8-10 min) Play the Khan Academy video "Binary and Data" to introduce these concepts to your students:
https://www.khanacademy.org/computing/code-org/computers-and-the-internet/how-computers-work/v/khan-academy-and-codeorg-binary-data

Recap the video and discuss by asking students the following:

- *What are bits?* "Binary digits". Physically, they are single wires in the computers that can be switched off or on to represent 0 or 1. Bits are the smallest amount of information that can be stored in a computer.
- *What can bits represent?* Any two things that are opposite – 0 and 1; true and false; heads and tales; up and down; black and white; etc…
- *What are some kinds of information that we can store in bits?* Numbers, letters, sounds, images

Step 2: (6-8 min) Explain/practice the binary number system

Explain to the students the difference between the decimal and binary numbering systems. It can be helpful to use a graphic like this on a slide or just drawn on the board:

Decimal: 0 through 9

$10^3 = 1000$	$10^2 = 100$	$10^1 = 10$	$10^0 = 1$

Binary: 0 through 1

$2^4=16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$

Depending on the grade level, instead of using exponents, you may just want to point out that we multiply by 2 (vs 10) to get the next digit in binary (vs decimal). Do an example of how to write a decimal number as a binary number.

For example, here's how we can write the decimal number 29 in binary:

🌶🫑🫑🫑🌶/🌶🫑🌶🫑🌶/🫑🫑🫑🫑🌶/🫑🌶🌶🌶🫑/🌶🫑🌶🫑🫑/🫑🌶🫑🫑🌶/🫑🌶🌶🫑🌶/🫑🫑🫑🌶🫑/🫑🫑🌶🫑🌶

1. How many times does 16 go into 29? 1 time, so the number in the 16's column will be 1. Now subtract 29-(1x16) = 13.
2. How many times does 8 go into the remainder 13? 1 time, so the number in the 8's column will be 1. Now subtract 13-(1x8) = 5.
3. How many times does 4 go into the remainder 5? 1 time, so the number in the 4's column will be 1. Now subtract 5-(1x4) = 1.
4. How many times does 2 go into the remainder 1? 0 times, so the number in the 2's column will be 0. Now subtract 1-(0x2) = 1.
5. How many times does 1 go into the remainder 1? 1 time, so the number in the 1's column will be 1.

So the number 29 in binary is 11101.

As practice, have students write their age (or some other number) in binary. Students can work in pairs and help each other out. After a few minutes, regroup and ask students to share the binary numbers and have the rest of the class decode their age/number if time permits.

Step 3: (8-10 min) Explain/practice converting text into binary.

Explain to the students how we can assign each letter of the alphabet to a decimal number and then convert that number to binary. It can be helpful to use a graphic like this on a slide or just drawn on the board:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

Do an example of how to write your initials in binary.

For example, if your initials are CAT, here's how you would convert it to binary. First, convert the letters into digital numbers using the table above.
C = 3
A = 1
T = 20

Then use the method in the previous part to convert those numbers to binary.
C = 3 = 00011
A = 1 = 00001
T = 20 = 10100

So we would write CAT as 00011 00001 10100.



As practice, have students write their initials in binary. Students can work in pairs and help each other out. After a few minutes, regroup and ask students to share the binary numbers and have the rest of the class decode their initials if time permits.

Step 4: (15 min) Make binary friendship bracelets

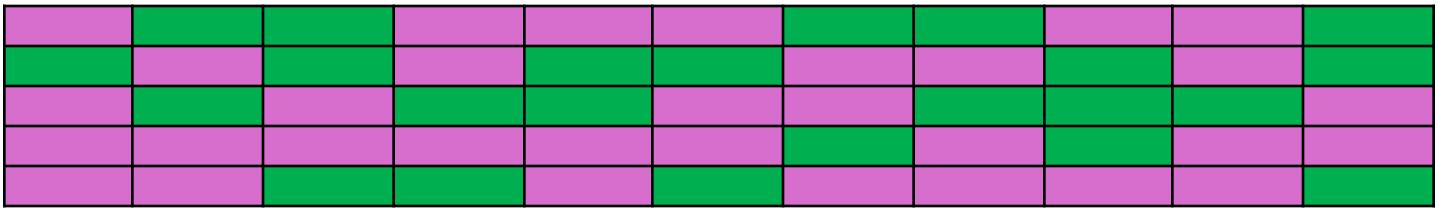
Explain to students that we're going to make friendship bracelets using the concepts we just learned. Pass out one blank binary friendship bracelet to each student. Students should choose a friend to work with for the following:

1. Choose a short message you'd like to share with your friend.
2. Write that message out using letters.
3. Convert each of the letters to a decimal number.
4. Convert each of the decimal numbers to a binary number.
5. Color in the binary bracelets.

For example:

BEST FRIENDS

B	E	S	T	F	R	I	E	N	D	S
2	5	19	20	6	18	9	5	14	4	19
00010	00101	10011	10100	00110	10010	01001	00101	01110	00100	10011



When students have finished coloring in their messages, tape the bracelets around their wrist to wear it.

Tie to Quantum Computing: Quantum computers also use a special kind of bits called quantum bits or "qubits". Qubits are much smaller objects than the wires in your computers, but they still have a "0" state and a "1" state. But they can also be in a superposition, where they are a combination of both a "0" and "1". How might we represent a superposition in our binary bracelets? Use a color that is in between the two colors they chose for 0 and 1, or color half of a box in each color…

CONSIDERATIONS FOR DIFFERENT GRADE LEVELS

Elementary School: Instead of expecting students to pick up the math behind the binary numbering system, just show them a list of the letters corresponding with their binary representation like the one below. Also consider having them color in the simpler bracelet templates with just the first letter of their first name rather than a whole message.

Middle/High School: Instead of representing each letter with 5 bits, consider introducing them to bytes (8-bits) and ASCII. To convert capital letters to binary ASCII code, each byte will begin with

0	1	0					

A					■
B				■	
C				■	■
D			■		
E			■		■
F			■	■	
G			■	■	■
H		■			
I		■			■
J		■		■	
K		■		■	■
L		■	■		
M		■	■		■
N		■	■	■	
O		■	■	■	■
P	■				
Q	■				■
R	■			■	
S	■			■	■
T	■		■		
U	■		■		■
V	■		■	■	
W	■		■	■	■
X	■	■			
Y	■	■			■
Z	■	■		■	

Additional Resources:

- Text to Binary converter: https://www.rapidtables.com/convert/number/ascii-to-binary.html
- Similar code.org lesson titled “Binary Bracelets”: https://studio.code.org/s/coursec-2022/lessons/15
- Similar code.org/Thinkersmith lesson titled “Binary Baubles”: https://code.org/files/CSEDbinary.pdf
- Similar NASA lesson with images entitled “Quantum Code Crunchers”: https://q12education.org/project/quantum-code-crunchers

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