Nim Lesson Plan

Summary

Games that involve strategy can be very effective tools for teaching computational thinking, as the approaches used to win games are often similar to the types of thinking required to solve problems using a computer. The game of **Nim** is a mathematical game that has been studied for centuries. Several variants exist; this activity uses a specific variant called **Single Pile Nim**. In this lesson students will learn not only how to play Single Pile Nim, but guarantee that they can always win given certain starting conditions.

Time Line

What	**Time Required**	**Where**
Introduction	5 minutes	Lesson plan
Nim Pairs Activity	10 minutes	Lesson plan
Scratch Demo 1 Strategy Explanation	10 minutes	Nim 12 Marbles simulation: https://scratch.mit.edu/projects/147398241/
Discussion with Scratch demo	10 minutes	Nim Random Marbles simulation: https://scratch.mit.edu/projects/147437713
Nim Pairs Activity 2	10 minutes	Nim Winning Strategy Worksheet
Wrap-Up Discussion	5 minutes	Lesson plan
Total time	50 minutes	

Materials Required

- ✓ 12 objects (e.g., pencils, sticks, marbles, pennies) per pair of students. To save time during activity, you may want to count these ahead of time and place into baggies.
- ✓ Computer & projection system (for Scratch demos, must be able to use Flash player)
- ✓ One copy of Nim Winning Strategy worksheet for each pair of students

Purpose

This CS Unplugged lesson helps the students discover the fundamentals of *problem decomposition* and *algorithmic thinking* by example through Nim.

Introduction - Whole Class

When deploying this activity, start by telling the students that they are going to learn how to play a strategy game. The rules for Nim are:

1. Start with 12 sticks in a pile
2. During each turn, players take 1, 2, or 3 sticks from the pile. You cannot pass on your turn.
3. The person to take the last stick wins.

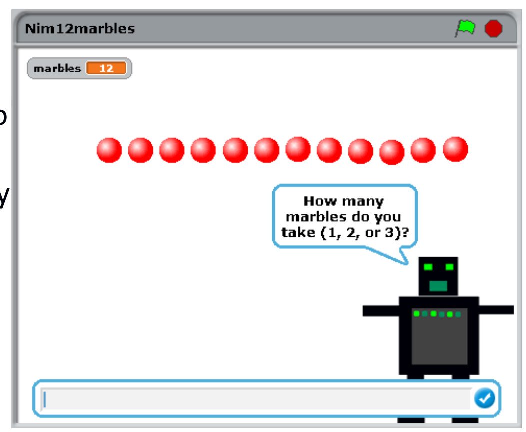
Draw 12 “sticks” on the board and have a volunteer play a sample round with you in front of the class for demonstration.

Nim Pairs Activity 1

Now students will work in pairs to play a few games of Nim. An odd number of students will result in one group of 3. Pass out the sets of 12 objects (buttons, pennies, etc.) and tell the students to take turns going first. Challenge them to see if they can figure out a strategy to win the game.

You can decide how much time to spend on this portion of the activity. Typically, you can let them play for about 10 minutes.

Scratch Demo 1



Next, show the Nim12marbles Scratch demo using a projection system. Click the icon in the top left corner to display the demo full screen. Click the green flag in Scratch to start the demo once the file has opened. You can have a student try to play against the demo (enter the numbers they tell you).

After the first game, ask the students if they think the computer will always win. [**answer**: it will]

Play again, but this time, ask the students if they can predict the number of sticks the computer will take during its turn.

See if any students can explain the strategy. If any of the strategies seem promising, maybe try them on the whiteboard. Otherwise, explain the strategy below:

Nim Strategy Explanation

You'll want to explain how the computer program always wins. The 12 marbles demo makes this easy to show. We will work backward from the desired final state.

- If there are zero marbles and you just played, obviously you just won. Maybe write this on the board as "You Win!"
- If there are four marbles and you just played, the other player may only take 1, 2, or 3 marbles of the four, so you can guarantee a win. Draw the last four marbles from figure 1 on the whiteboard.
  - If other player takes 1 stick, you can take 3 to win.
  - If other player takes 2 sticks, you can take 2 to win.
  - If other player takes 3 sticks, you can take 1 to win.
- Likewise, if there are eight marbles and you just played, the other player may only take 1, 2, or 3 marbles of the eight, so you can leave them with four after your turn, guaranteeing a win. Draw four more marbles on the whiteboard.
- Have the students tell you what to draw next (four more marbles, to reach 12)
- Ask the students if the strategy would still work if there were more than 12 [**answer**: yes, 16, 20, 24 etc. You may use this question to reinforce the mathematical concept of *multiple*, because this strategy would work for any multiple of four.]

Drawing a picture like Figure 1 may help explain this:

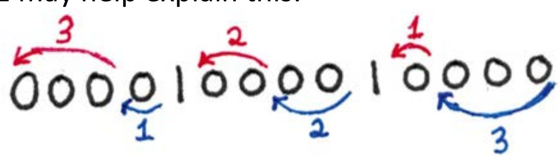


Figure 1: Winning Strategy for NIM

Discussion - Whole Class

After students have created their algorithms, lead a discussion using the questions below. Note that some of these questions may arise naturally during the discussion of game strategy.

- If *you have to go first* and there are 12 sticks in play, can you be certain that you will win?

  No. You might win, but if your opponent is playing the winning strategy you will lose.

- If the number of sticks in the pile is a multiple of four (e.g., 12, 16, 20) and you want to win, who should go first?

  Let the other person go first. This uses our strategy described above.

- If the number of sticks in the pile is some number that is *not* a multiple of four, can you still win?

  Yes, but now you should go first. On your first turn, reduce the number of sticks to a multiple of four (e.g., if there are 15 sticks, take 3. Now there are 12, and it's the other persons turn… so you know how to win).

  The Scratch demo NimRandomSticks shows this by selecting a random number of sticks at the start, and deciding who plays first based on the number of sticks in play.

- So if someone else is choosing the number of sticks, what can you do to be certain you will win?

  Using the strategy explained above, let the other player go first if there are a *multiple of four sticks,* otherwise you go first.

- Sometimes Nim is played so that taking the last stick/marble now makes you *lose* rather than win. What strategy can you now use to always win?

  Playing a game under these new rules is just like playing a game under the old rules with one less stick in play. This time, you want the opponent to be left with one stick rather than zero, five rather than four, etc.

  This might be easy to explain using a picture:

Marble of Doom!

Nim Pairs Activity 2

Hand out the “Nim Winning Strategy” worksheet. Explain that if the worksheet is completed correctly, students could give it to their friends and the friend could follow the instructions and win. Computers also need very specific instructions, and this worksheet is an example of an *algorithm* (step-by-step process). Students can work individually or in pairs (your choice) to fill in the blanks to complete the algorithm.

What’s It All About - Whole Class Discussion

We came up with a strategy for winning Nim by first solving the problem for a very simple case (only four sticks), then figuring out how to turn more complex problems into that simple one. This is called *problem decomposition*. For our Nim strategy, solving the larger problem used exactly the same process. But for many problems, decomposition is just figuring out lots of small problems that you can solve, that ultimately get to your desired solution.

Ask the students if they can think of situations where this strategy might work?

- If you want to solve a maze, start by figuring out how to solve a smaller section of the maze.
- If you are writing a game, you might first define what each character does.
- If you want to understand a sentence, you figure out what the individual words or phrases mean.

Tell the students that the computer is following a step-by-step process, called an *algorithm*, that lets it win (maybe write *algorithm* on the board). Ask if any of the students own or have seen robots. How do robots “know” what to do? Answer: they follow very detailed instructions - algorithms.

What other games can be won if you know the right algorithm? Many… students can probably mention quite a few.