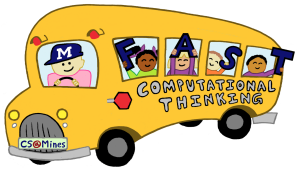
NIM [DRAFT]



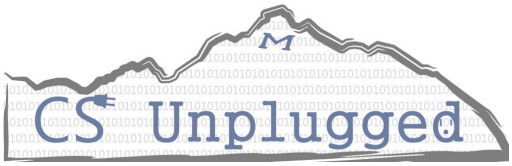
Summary

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 how to (1) play Single Pile Nim and (2) guarantee that they can always win given a certain starting condition.

Grade Level: 5th - 6th

Subject: Computer Science
Problem Decomposition

Length: 50 min.



CSTA/Common Core Standards Alignment

CSTA - Algorithms and Programming - 1B-AP-09
Create programs that use variables to store and modify data
Students will use variables when generalizing their NIM algorithm to fit any number of sticks.

CSTA - Algorithms and Programming - 1A-AP-11
Decompose (break down) problems into smaller, manageable subproblems to facilitate the program development process.
The NIM problem can be broken down into smaller digestible steps.

Computational Thinking Alignment

Problem Decomposition
Students break the game down into different amounts of sticks to formulate a solution. Can we solve the game for 4 sticks? 8 sticks? 9 sticks? Decomposing the problem this way helps create a winning strategy.

Algorithmic Thinking
Students develop the steps to follow that always produces a winning result.

Pattern Recognition
Students analyze NIM (while playing) to recognize the pattern of why the computer always wins.

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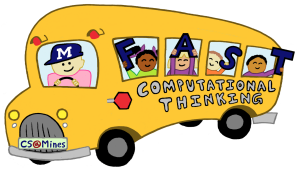

Objectives

The objective of this CS Unplugged lesson is to help students discover the fundamentals of problem decomposition and algorithmic thinking by example through the game of Nim.

Timeline

Activity	**Time**	**Activity Location**
Introduction	5 min	Lesson Plan
Nim Pairs Activity	10 min	Lesson Plan
Scratch Demo 1 - Strategy Explanation	10 min	Nim 12 Marbles Simulation: https://scratch.mit.edu/projects/147398241/
Scratch Demo 2 - Discussion	10 min	Nim Random Sticks Simulation: https://scratch.mit.edu/projects/147437713
Nim Pairs Activity 2	10 min	NIMWorksheet.pdf
Wrap-Up Discussion	5 min	Lesson Plan
Total Time	**50 min**	

Materials

- ❏ Objects for Game (e.g. pencils, sticks, marbles, pennies) 12 Per Student
- ❏ Computer & Projection System (optional for demo - need flash player) 1
- ❏ NIMWorksheet.pdf 1 per student

Attachments

- NIMWorksheet.pdf

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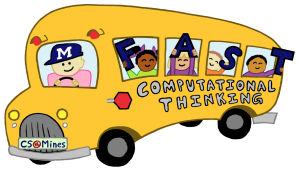

Preparation

Prior to class, you may want to count and place 12 objects in a bag for each student. Handing each student a bag of 12 objects will reduce time in the distribution of materials.

Procedure

Introduction

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.

Vocabulary

- Algorithm: step-by-step instructions that are followed to accomplish a task
- Problem Decomposition: Breaking a complex problem into smaller subproblems that are easier to solve

Body of Lesson and Activities

Nim Pairs Activity 1

Pair students in class and have them play a few games of Nim. Pass out the bags of 12 objects (buttons, pennies, etc.) and tell students to take turns going first. Challenge students to see if they can determine a strategy to win the game.

Allow students to play for about 10 minutes. Allow more or less time depending on what else you have to accomplish.

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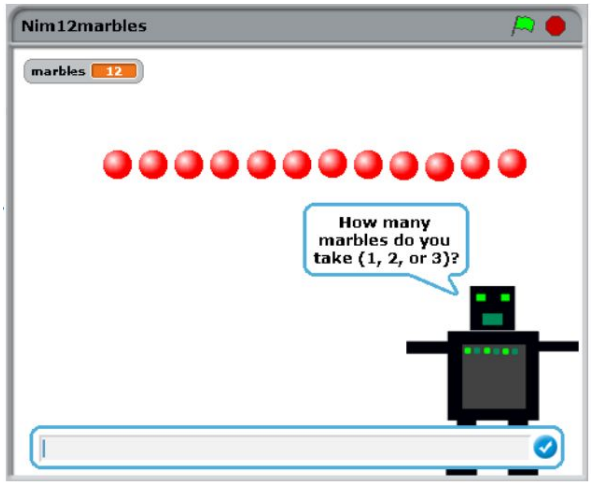
Scratch Demo 1

Show the Nim 12 Marbles Simulation Scratch demo (link on page 2) using a projection system. Display the demo full screen and then click the green flag in Scratch to start the demo. Choose a student to play against the demo (e.g., enter the numbers they tell you).



If you do not have access to a computer and projector system, you can also demonstrate the game on the board. In this case, you act as the computer and tell the students that you think you have the best strategy for this game.

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, try them on the whiteboard. Otherwise, explain the strategy below.

Nim's Winning Strategy

Work with the students to determine how the computer is always winning. The 12 Marbles Simulation Scratch demo will help students to understand. We will work backward from the desired final state. Tell students the current state of the game, and then ask the students what to do for this case (i.e. "If there are zero marbles and you just played, what should you do?"). This will allow students to engage in the decomposition of the problem into stages, then develop an algorithm to accomplish those individual steps.

- If there are zero marbles and you just played, obviously you just won. Write this case on the board as "You Win!"
- If there are four marbles and you just played, the other player must take 1, 2, or 3 marbles of the four and you can guarantee a win. Draw the last four marbles from Figure 1 on the whiteboard. (The figure is on the next page.) Ask students:
    - If the other player takes 1 marble, you should take ?? (3) to win.
    - If the other player takes 2 marble, you should take ?? (2) to win.
    - If the other player takes 3 marble, you should take ?? (1) to win.

- Likewise, if there are eight marbles and you just played, the other player must take 1, 2, or 3 marbles of the eight, and you can leave them with four marbles after your turn (also guaranteeing a win). Draw four more marbles on the whiteboard.
- Ask the students tell you what to draw next (four more marbles, to reach 12)
- Ask the students if this strategy still works if there are more than 12 marbles [answer: yes, 16, 20, 24 etc]. You may use this question to reinforce the mathematical concept of multiple; this strategy always works for any multiple of four.

Drawing a picture like Figure 1 may help explain the strategy:

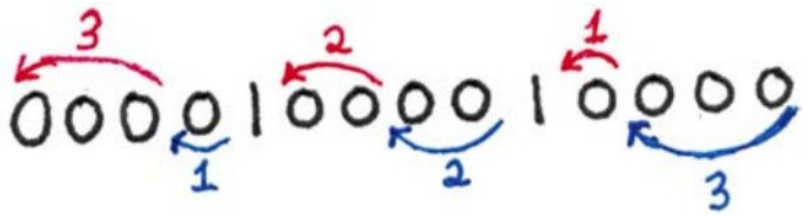


Figure 1: Winning Strategy for NIM

Discussion - NIM Strategy

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

- **If you have to go first and there are 12 sticks in play, can you guarantee a win?**

  No. You might win (unless your opponent is playing the winning strategy).

- **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?**

  The other person should go first, and then you should use the winning strategy.

- **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 be a multiple of four. For example, 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 Nim Random Sticks Simulation (see Scratch demo link on page 2) often illustrates this. A random number of sticks is chosen; who plays first is based on the number of sticks in play.

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

  Let the other player go first if there are a multiple of four sticks; otherwise you should go first.

- **Sometimes Nim is played so that taking the last stick/marble now makes you lose rather than win. In this case, shat strategy should you 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.

Nim Pairs Activity 2

Hand out the “Nim Winning Strategy” worksheet. Tell students to complete the worksheet correctly and then share with a friend. If the friend follows the instructions, the friend will always win. Then tell students that 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 and complete the algorithm.

Discussion

We developed 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 cases into that simple case. This is called problem decomposition. For our Nim strategy, solving the more complex case used exactly the same process. For many problems, however, decomposition is figuring out lots of small problems that you can solve, that ultimately result in the desired solution.

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

- If you want to solve a maze, start by figuring out how to solve a small 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 can first 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 the word “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.