Beyond Sudoku: Using Puzzles to Develop Students’ Logical-Thinking Skills

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Some cells start out with numbers from 1 to 8 inclusive—these are the islands. The goal is to connect all of the islands into a single connected group by drawing a series of bridges between the islands. The bridges must follow certain criteria:

- They must begin and end at distinct islands, traveling a straight line in between (horizontally or vertically)
- They must not cross any other bridges or islands
- At most two bridges connect a pair of islands
- The total number of bridges connected to each island must match the number on that island
• What strategies did you use to find the solution?
• What methods of notation did you use?
Logic Puzzles

• Many different puzzle types have been around for decades

• Popularity increased when Sudoku took off in 2004

• Since then, logic puzzles have started to appear more regularly in books, TV, magazines, movies, and on the Internet
ARE YOU SURE YOU DON'T MEAN "SUDOKU"?

LIKE MY SUDOKU?

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Inside Japan’s Puzzle Palace

By MARTIN FACKLER

TOKYO, March 20 — Will there be another puzzle craze after sudoku?

Perhaps kakuro? What about nurikabe?

If so, chances are it will spring from a Japanese company called Nikoli, run by the self-proclaimed godfather of sudoku, Maki Kaji.

Few Americans had ever thought of Japan as a source for puzzles until a little more than two years ago, when sudoku suddenly took the nation by storm, flooding airport gift shops, and even rivaling crosswords in popularity. Now Nikoli, which publishes puzzle magazines and books, is widely regarded as the world’s most prolific wellspring of logic games and brainteasers.

Mr. Kaji and the company have had a hand in creating and promoting most of the half dozen or so number puzzles that have taken off after sudoku. But Mr. Kaji says that Nikoli has at least 250 more puzzles like sudoku, the vast majority of them unknown outside Japan.

Nikoli’s secret, Mr. Kaji says, lies in a kind of democratization of puzzle invention. The company itself does not actually create many new puzzles — an American invented an earlier version of sudoku, for example. Instead, Nikoli provides a forum for testing and perfecting them. About 50,000 readers of its main magazine submit ideas; the most promising are then printed by Nikoli to seek approval and feedback from other readers.

That process allows Nikoli to tap into the insatiable urge of Japanese puzzle solvers to tinker and improve, a drive its readers apply to games with the intensity of Toyota’s engineers trying to outdo Detroit’s automakers. Most of Nikoli’s games are original, says Mr. Kaji, but a few, like sudoku and kakuro, are improved versions of older games invented elsewhere.

Mr. Kaji believes that the world is hungry for more Nikoli puzzles. When he visited New York in December, he said, publishers were besieging him for new puzzles in hopes of creating the next rage.
The Next Sudoku?

Kakuro is simply elegant, nurikabe ends in a rush of excitement, while masyu has no numbers. Could one of these three logic puzzles from Nikoli, a puzzle magazine publisher, become as popular as sudoku?

HOW TO PLAY  Complete the grid by entering the digits 1-9 in the empty squares. The sum of the digits in each answer across or down equals the given number immediately preceding it. No digit is repeated within an answer. There is only one solution to the puzzle shown here.

WILL SHORTZ’S SOLVING TIME
5 minutes 30 seconds
The Next Sudoku?

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KAKURO  MASYU  NURIKABE

HOW TO PLAY  "String" all the black and white "pearls" into a single, continuous loop. The loop must proceed horizontally or vertically (never diagonally) through the squares.

A line going through a white pearl must proceed straight through the pearl, but it must turn 90 degrees in the previous and/or next square in its path.

A line going through a black pearl must turn 90 degrees at the pearl and then continue straight for at least one more square in each direction.

Not all squares need to be used in the string.

There is only one solution to the puzzle shown here.

WILL SHORTZ'S SOLVING TIME
9 minutes 15 seconds
A note from Mr. Shortz: "Masyu isn't as hard as this time may suggest. I got tangled up after making a mistake, which took me awhile to undo."

See How to Play
The Next Sudoku?

Kakuro is simply elegant, nurikabe ends in a rush of excitement, while masyu has no numbers. Could one of these three logic puzzles from Nikoli, a puzzle magazine publisher, become as popular as sudoku?

HOW TO PLAY  The object is to determine which squares in the grid are white ("islands") and which are black ("water").

Each numbered square must belong to an island of white squares connected on their sides. The number indicates the number of white squares connected. Every island has exactly one numbered square. Two islands cannot touch except at their corners.

The black squares in the completed grid must all be contiguous (forming a single chain of squares connected on at least one side). There cannot be any 2-by-2 blocks of black squares.

There is only one solution to the puzzle shown here.

WILL SHORTZ'S SOLVING TIME
3 minutes 50 seconds
Logic Puzzles in the Classroom

• These puzzles also serve as an excellent launching point in the discussion of problem-solving, reasoning, and communication

• Today we will explore different puzzles, strategies for finding solutions, methods for representing one’s work, and ideas for incorporating them into the classroom
Deductive Reasoning

• Students can be taught the basics of deductive reasoning by having them explain their thinking while solving a specific step of a logic puzzle.

• This practice can be helpful for establishing good deductive reasoning skills that will be useful in later mathematics.
Bridges

- First appeared in the Japanese puzzle magazine *Puzzle Communication Nikoli* in 1990 under the name *hashiwokakero* (build bridges)
- These puzzles typically don’t require using logic beyond one or two steps away from the current position
What strategies can you develop for solving these?
Bridges

Bridges Puzzle 2 - Solution

Bridges Puzzle 3 - Solution
Bridges Resources

- **HASHI: The Bridges Puzzle** by Alastair Chisholm (2006)
- Occasional GAMES and GAMES World of Puzzles magazines
- Online applets:
  - A few hand-created Hashi-o-Kakero puzzles (more visually interesting grids with rotational symmetry of islands) at [http://www.redbrick.dcu.ie/~kevmcg/bridges/](http://www.redbrick.dcu.ie/~kevmcg/bridges/)
Logic (and therefore probability as a branch of logic) is not concerned with what men do believe, but what they ought to believe, if they are to believe correctly.

John Venn
There are a number of types of puzzles built around a set of dominoes. In this version, a 7x8 grid contains a full set of double-six dominoes. Numbers are often used in place of the pips. The challenge is to find where the boundaries of the dominoes lie.
**Dominoes**

- What strategies did you use to find the solution?
- What methods of notation did you use?

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Dominoes Puzzle 1 - Solution
Dominoes

- Dominoes puzzles have existed for some time—Sam Lloyd used dominoes in some of his famous puzzles (late 19th century).

- Dominoes puzzles come in many variations: numbers of dominoes (e.g. double-sixes or double-nines) and shape of grid.
## Dominoes

### Strategies for solving?

#### Dominoes Puzzle 2

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Dominoes - Solutions

Dominoes Puzzle 2 - Solution

Dominoes Puzzle 3 - Solution
Dominoes Resources

- Occasional GAMES and GAMES World of Puzzles magazines
Ed Pegg, Jr. created this Sudoku variation, writing “…I started wondering if a set of dominoes + monominoes could be used to make a Sudoku. I constructed the puzzle … entirely by hand, because my program was getting nowhere. I'm hoping to make a 16x16 Domino Sudoku out of a double-15 set sans doubles and a 4x4 magic square.”

http://www.maa.org/editorial/mathgames/mathgames_09_05_05.html
Once you have eliminated the impossible, whatever remains, however improbable, must be the truth.

Sherlock Holmes
Battleships
Battleships

- In the answer grid for this type of puzzle, 10 ships—one battleship (4 cells long), two cruisers (3 cells each), three destroyers (2 cells each), and four submarines (1 cell each)—are placed horizontally and/or vertically on a 10 x 10 grid so that no two ships are touching—not even diagonally. Water is placed in all remaining squares.
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Along the perimeter of the grid, numbers are placed to indicate the total number of ship segments found in each row and column.
Battleships

• In the answer grid for this type of puzzle, 10 ships—one battleship (4 cells long), two cruisers (3 cells each), three destroyers (2 cells each), and four submarines (1 cell each)—are placed horizontally and/or vertically on a 10 x 10 grid so that no two ships are touching—not even diagonally. Water is placed in all remaining squares.

• Along the perimeter of the grid, numbers are placed to indicate the total number of ship segments found in each row and column.

• For the starting grid, most of the ship and water pieces are removed, leaving only a few clues in the grid.

• To solve the puzzle, you must use these clues together with the numbers on the outside of the grid to help you determine where the entire fleet is hiding.
• This puzzle is a solitaire version of the classic paper-and-pencil game of Battleships. The grid represents a section of ocean in which a fleet is hiding. This fleet consists of one battleship (four grid cells in length), two cruisers (three cells each), three destroyers (two cells each), and four submarines (one cell each). The ships may be oriented horizontally or vertically, and no two ships can occupy adjacent grid cells, not even diagonally. The digits along the grid’s perimeter indicate the number of cells in the corresponding rows and columns that are occupied by vessels.

• You’ll notice that some “shots” have been taken to start you off. These may show water (indicated by wavy lines), a complete sub (a circle), the bow or stern of a ship (a rounded-off square), or a midsection of a battleship or cruiser (a square).
• What strategies did you use to find the solution?
• What methods of notation did you use?
The first Battleships puzzle appeared in the Spanish puzzle magazine *Humor and Juegos* in 1982, under the name “Batalla Naval”.

At the first World Puzzle Championship in 1992, Battleships and some variants made their appearance and are now a regular part of the contest.
Battleships

Strategies for solving?

Battleships Puzzle 2

Battleships Puzzle 3
Battleships

Battleships Puzzle 2 - Solution

Battleships Puzzle 3 - Solution

Strategies for solving?
Battleships Resources

• Every issue of GAMES and GAMES World of Puzzles magazines
• The Mountain Vista Software website contains:
  ★ Fathom It! - A downloadable PC version of Battleships in both a demo version (free with a number of sample games of different sizes) and a full version with hundreds of puzzles at: http://www.mountainvistasoft.com/index.htm
  ★ The “Battleship Puzzle Omnibus” - a detailed compendium of Battleships puzzle variants and links to Battleships puzzles used in various competitions (e.g., the World Puzzle Championship), monographs, and analyses of Battleships puzzles.
• Yubotu: Sink the Fleet in These Addictive Battleship Puzzles (2006) and Sit & Solve Travel Battleship Puzzles (2006) by Peter Gordon and Mike Shenk
Battleships Variations

**Either/Or Battleships**

**Hexagonal Battleships**

Battleship

Cruisers

Destroyers

Submarines
A good puzzle, it's a fair thing. Nobody is lying. It's very clear, and the problem depends just on you.

Ernö Rubik
Fences

- In this puzzle, a square arrangement of dots is used.
Fences

- In this puzzle, a square arrangement of dots is used.
- In the answer grid, a continuous closed fence is placed connecting dots horizontally and vertically.
Fences

- In this puzzle, a square arrangement of dots is used.
- In the answer grid, a continuous closed fence is placed connecting dots horizontally and vertically.
- Then, numbers are placed in each square indicating the number of sides of that square used in the fence.
Fences

• In this puzzle, a square arrangement of dots is used.
• In the answer grid, a continuous closed fence is placed connecting dots horizontally and vertically.
• Then, numbers are placed in each square indicating the number of sides of that square used in the fence.
• The fence is then removed for the starting grid, leaving all or some of the numbers.
Fences

Fences Puzzle 1

Fences Puzzle 2

What strategies did you use to solve these?
What arrangements of numbers produce specific results?
Fences puzzles are also known as “Slitherlink,” “Loop the Loop” and other names.

This puzzle type was created for the Japanese puzzle magazine *Puzzle Communication Nikoli* in 1989. The first version of this puzzle had every number included in the grid.

Now, the challenge in the creation of the puzzles is often to include as few starting numbers as possible, usually filling the starting numbers so that those cells have rotational symmetry in the overall grid—just as crossword puzzles do.
• Occasional issues of GAMES and GAMES World of Puzzles magazines
• A very challenging online version called “Kwon-Tom Loop” where a new puzzle is given each day. Solvers are timed and a leader board presents fastest score. “Easiest” puzzles appear on Mondays and the puzzles get more difficult and larger through the week. At: http://www.kwontomloop.com/index.php
• Millions of computer-generated Slither Link puzzles at http://www.puzzle-loop.com/
Logic is the art of going wrong with confidence.  
Joseph Wood Krutch

Logic is the beginning of wisdom, not the end.  
Mr. Spock
An electronic copy of the handout and a copy of this presentation can be downloaded from my web page at: http://www.users.muohio.edu/wankojj

More research about how students develop logical-thinking skills and what teachers can do to improve these skills using puzzles is forthcoming...