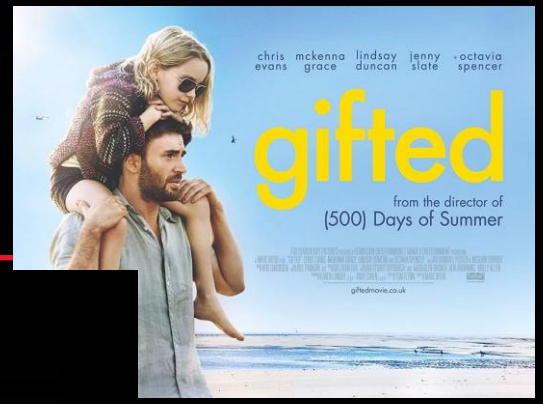
Computational Thinking and Mathematical Problem-Solving

Richard Hoshino

Northeastern
Khoury College of
Computer Sciences

Changing the Culture Conference
Simon Fraser University
May 16, 2025

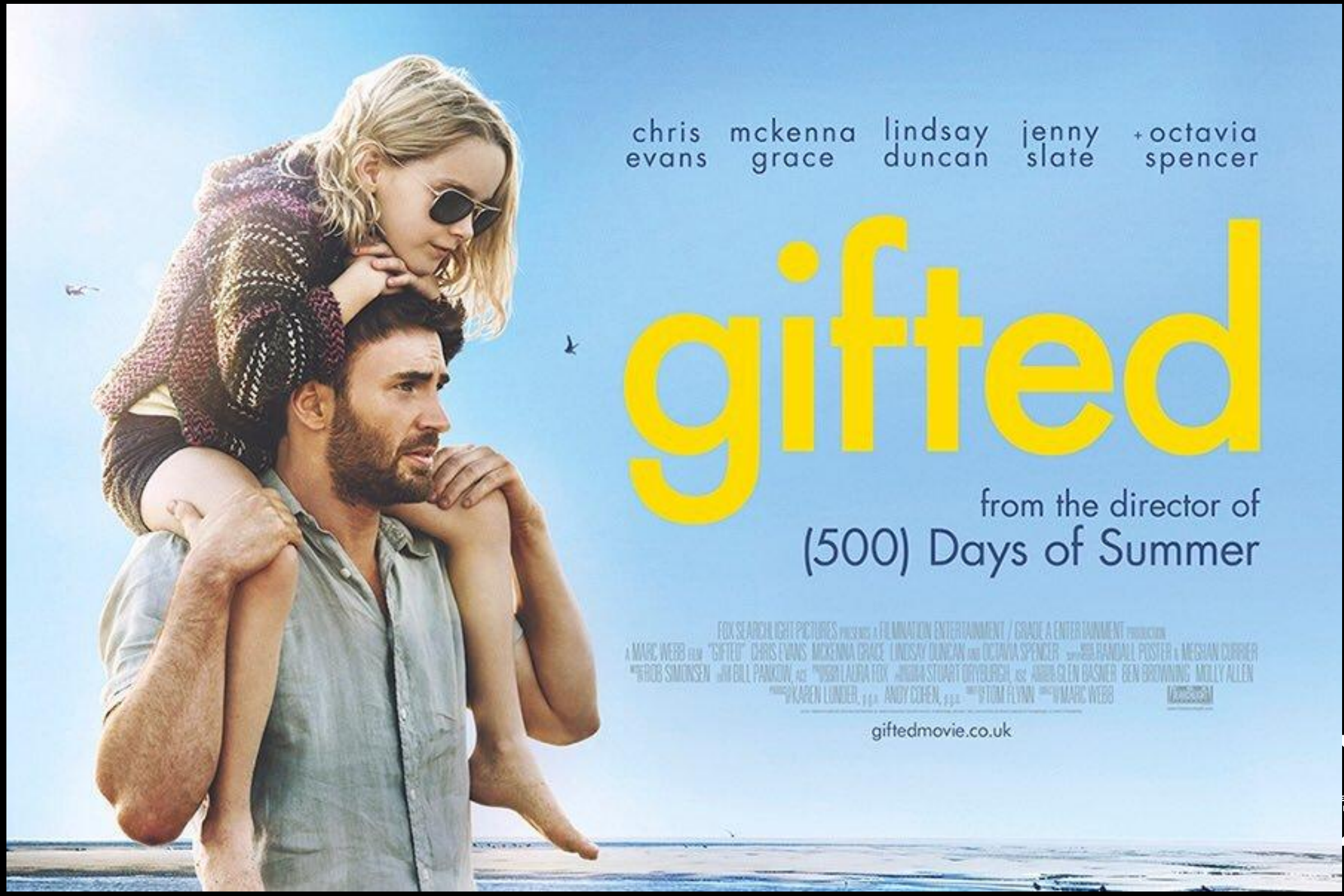
“Gifted” Movie Scene



LVX VERITAS VIRTVS

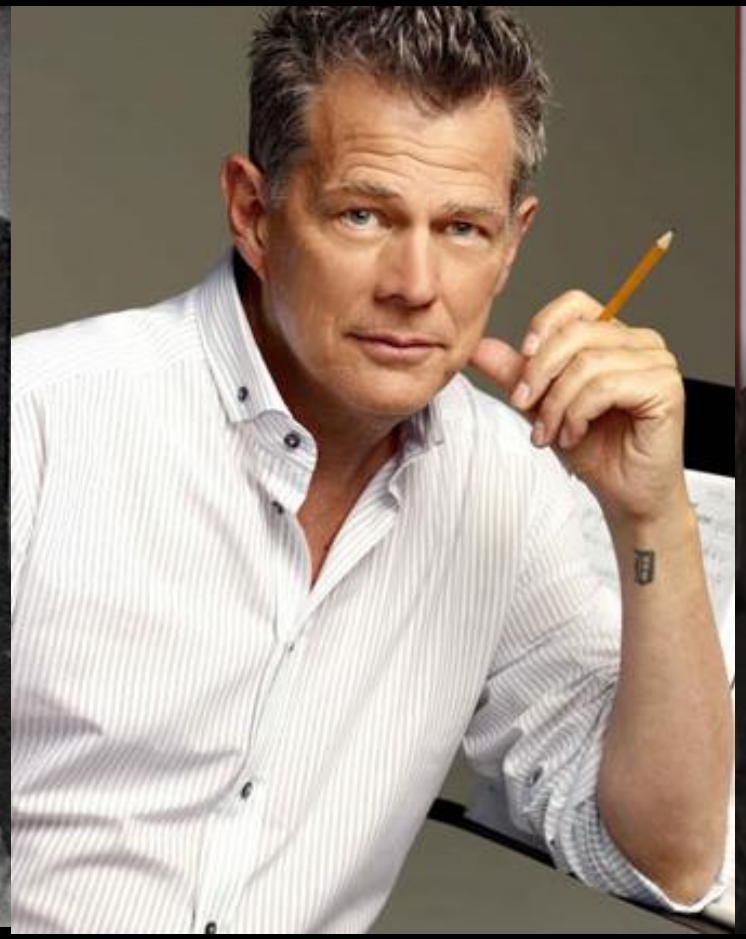

TORONTO STAR
Subscribe Now
As low as $0.99/week
Podcasts
Newsletters
HOME
MY LOCAL
GTA
CANADA
POLITICS
WORLD
OPINION
LIFE
SPORTS
ENTERTAINMENT
BUSINESS
Star Columnists
Editorials
Contributors
Letters To The Editor
Editorial Cartoons
COMMENTARY
OPINION
What it truly means to be gifted
RH
By Richard Hoshino
Mon., June 12, 2017
3 min. read


Problem
Show that $\int_{-\infty}^{\infty} e^{-x^2/2\sigma^2} dx = \sqrt{2\pi}|\sigma|$
Hint: First show that
$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{(x^2+y^2)/2\sigma^2} dx\,dy = 2\pi\sigma$


chris evans
mckenna grace
lindsay duncan
jenny slate
+ octavia spencer
gifted
from the director of
(500) Days of Summer
giftedmovie.co.uk

How Our Teachers Gifted Us

- They stretched us
- We wrestled with open-ended questions
- We spent time thinking deeply
- We received **authentic mathematical experiences**

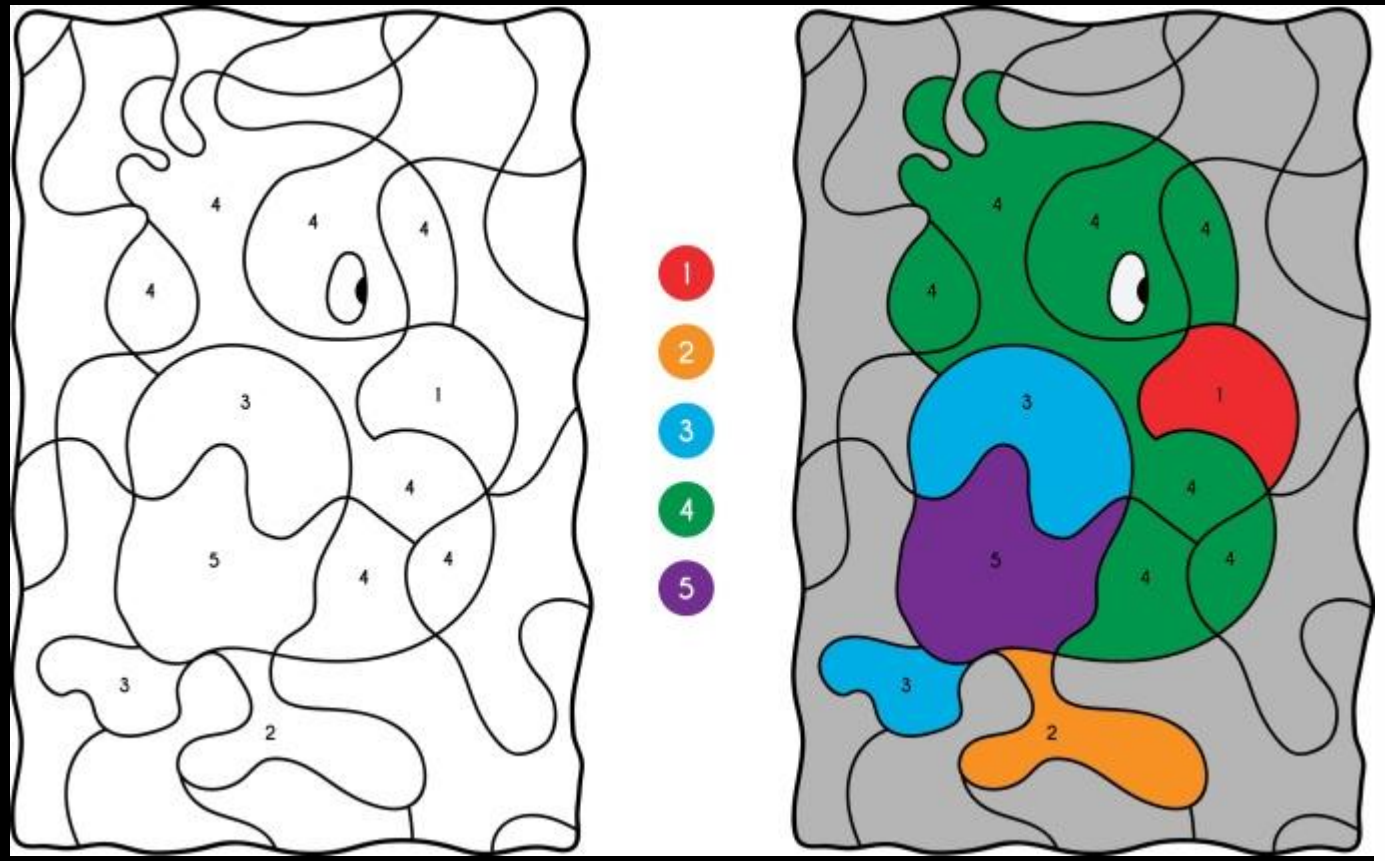

Quadratic Formula:

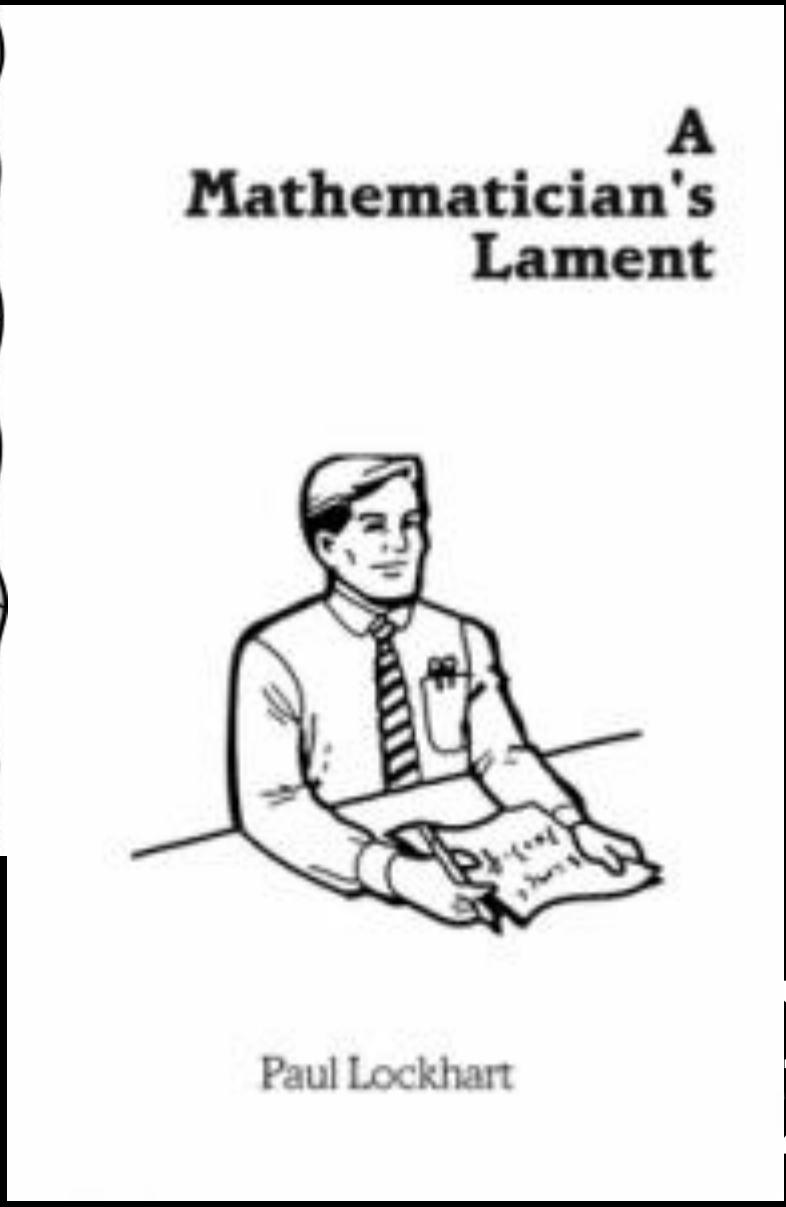
For $ax^2 + bx + c = 0$,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

MathBits.com

LVX
VERITAS
VIRTVS


1
2
3
4
5

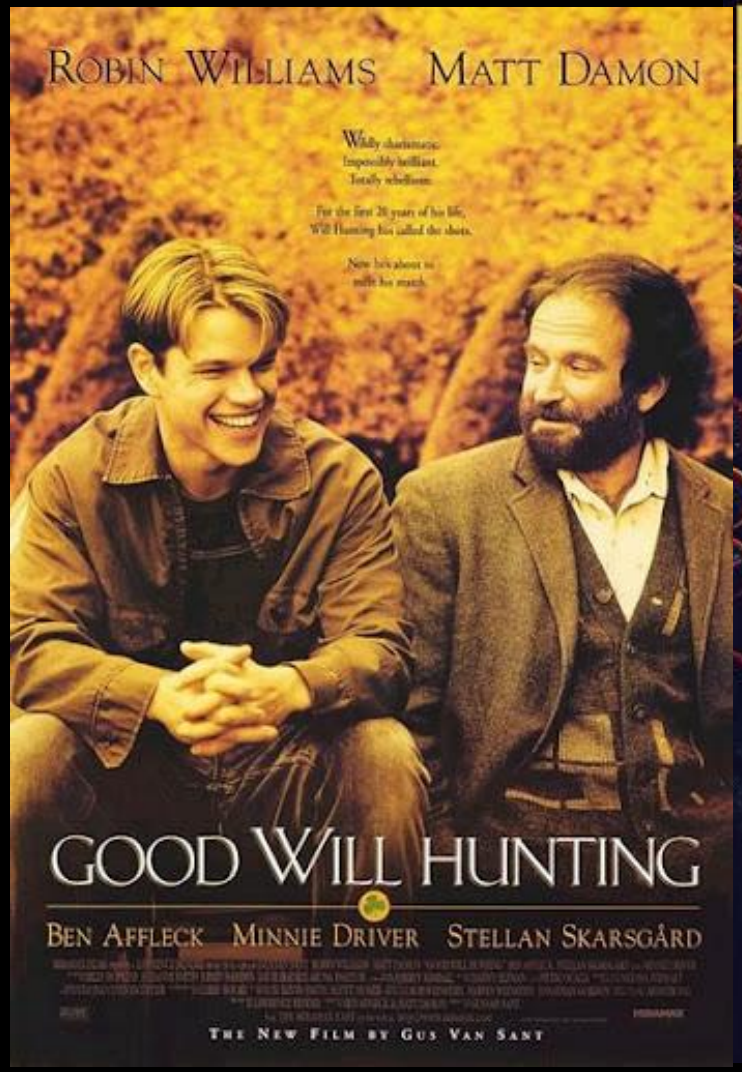

A
Mathematician's
Lament
Paul Lockhart

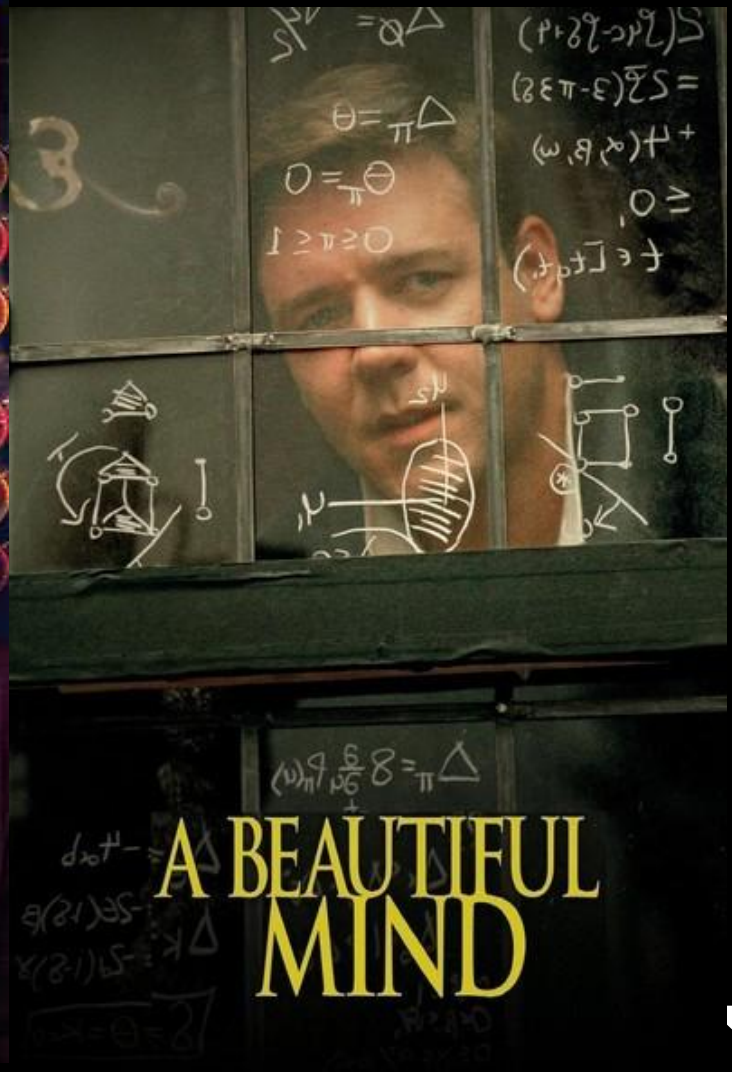
Authentic Mathematical Experiences

- Elementary School: learning ratios by making pancakes
- Middle School: figuring out interest rates
- High School: cutting costs of Campbell's Soup cans
- University: designing a roommate matching algorithm

Problem-Solving Process

- Getting stuck
- Finding and resolving cognitive obstacles
- Developing conceptual understanding
- Communicating solutions





LVX VERITAS VIRTVS


G
I
F
T
E
D


LVX
VERITAS
VIRTVS

Authentic Mathematical Experiences

(1) Biased Lottery Game (Lotto 3-7)

(2) Roommate Scheduling Puzzle

(3) Popular Children's Card Game (Spot It!)

The Lotto 3-7 Problem

You are on a 7-person team. It costs your team $200 to play this Lottery game.

Each of you get a ticket, consisting of three numbers from {1,2,3,4,5,6,7}. I then draw the winning combination, which is three numbers from this set.

Each ticket matching all 3 numbers wins $210. Each ticket matching 2 out of 3 numbers wins $70.

The Lotto 3-7 Problem

(1) What is the BEST set of 7 tickets you can pick?
Hint: what does “BEST” mean?

The Lotto 3-7 Problem

(1) What is the BEST set of 7 tickets you can pick?
Hint: what does “BEST” mean?

(2) Can you pick 7 tickets so that your team is GUARANTEED to make a profit?

The Lotto 3-7 Problem

Let’s play!

Anyone want to play for real money?

If you lose, you can send an e-transfer to me

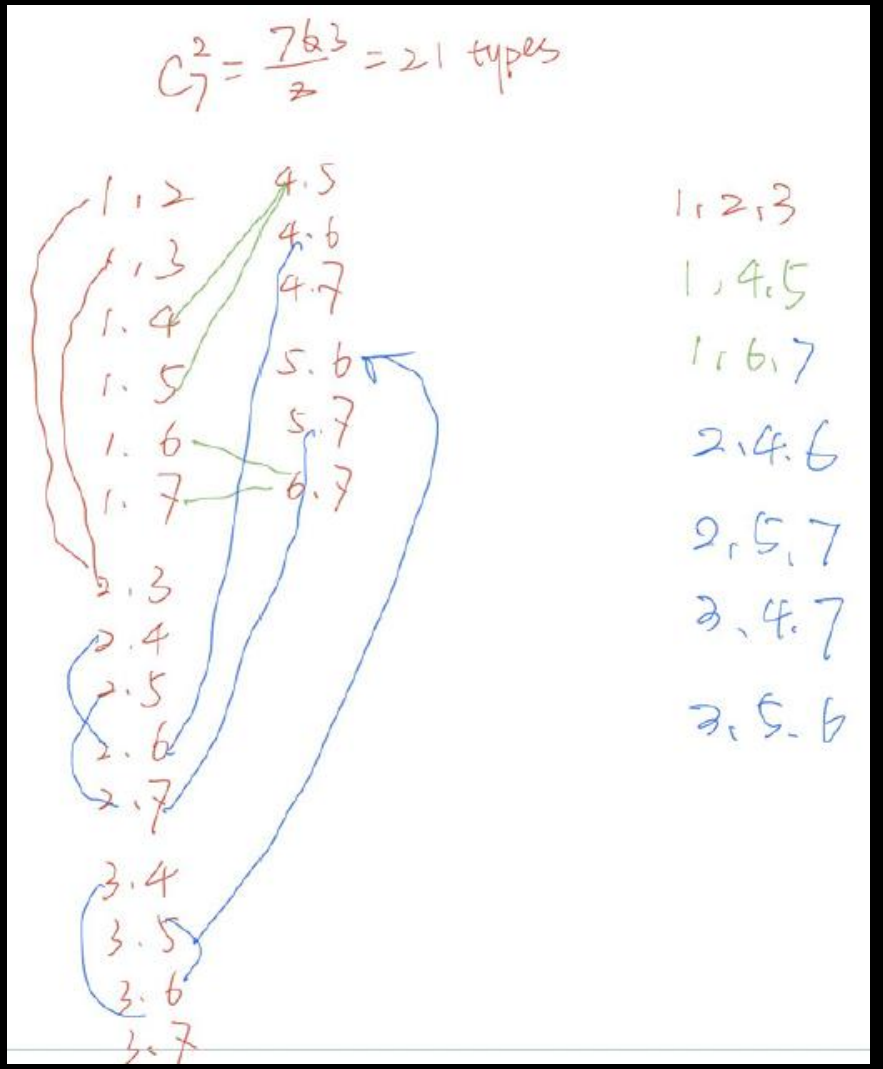
richard.hoshino@gmail.com

Optimal Solution

Key insight:

(1) Each number occurs exactly three times.

(2) Each pair of numbers occurs exactly once.



Optimal Solution

Suppose [1,2,3] is the winning ticket. There are (7 choose 3) = (7x6x5)/(3x2x1) = 35 total tickets.

Of the 35 tickets, exactly **1** matches all 3 numbers.

And exactly **12** match 2 out of 3 numbers.

[1,2,4],[1,2,5],[1,2,6],[1,2,7]

[1,3,4],[1,3,5],[1,3,6],[1,3,7]

[2,3,4],[2,3,5],[2,3,6],[2,3,7]

Optimal Solution

The **expected value** for each player's winnings is **1**/35 x 210 + **12**/35 x 70 = 30.

Thus, the expected value for the team is -200 + (30+30+30+30+30+30+30) = 10.

This is true for ANY choice of seven tickets!

Optimal Solution

In the optimal solution, the **variance** is 0.

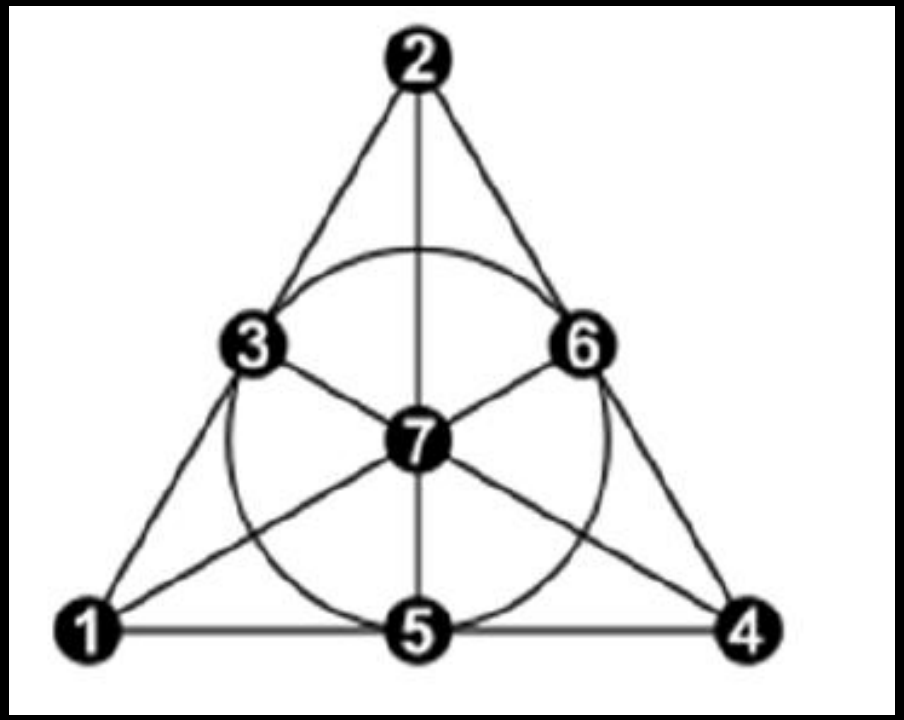
The team is guaranteed to win $10!

The Fano Plane

(1) Each point goes through three lines. The circle counts as a line!

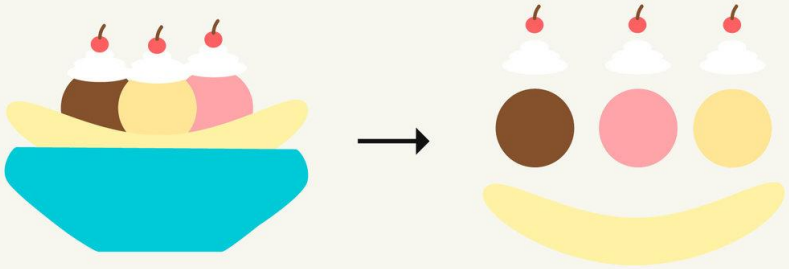
(2) Each line goes through three points. The circle counts as a line!

(3) Each pair of points touches exactly one line.



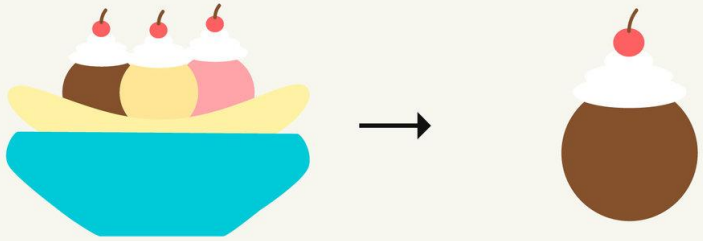
Computational Thinking

DECOMPOSITION

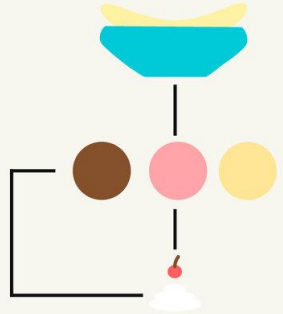


PATTERN RECOGNITION

ABSTRACTION



ALGORITHM



Computational Thinking

Decomposition: Break a problem into smaller parts

Pattern Recognition: Observe patterns and trends

Abstraction: Extract the most important information

Algorithm Design: Determine the steps needed to achieve the desired outcome

The Roommates Problem

Seven roommates create a schedule to do chores next week. Here are the rules:

- Each person must do chores on exactly three days.
- Each day must be covered by exactly three people.

You are given one “penalty point” for each instance where two people work together on two different days.

The Roommates Problem

Here is a solution with seven penalty points

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Asmita	x	x	x				
Bernard		x	x	x			
Cathery			x	x	x		
David				x	x	x	
Edward					x	x	x
Frederic	x					x	x
Gina	x	x					x

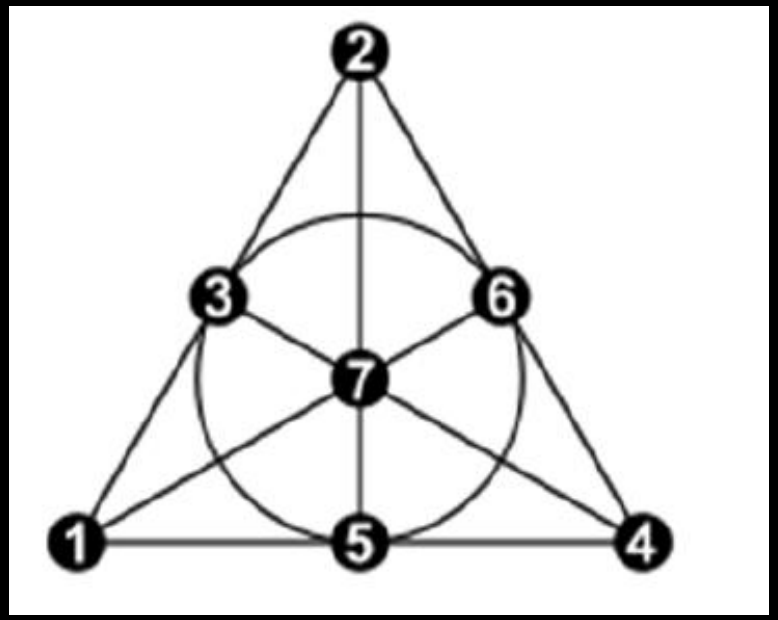
The Roommates Problem

Here is a solution with zero penalty points

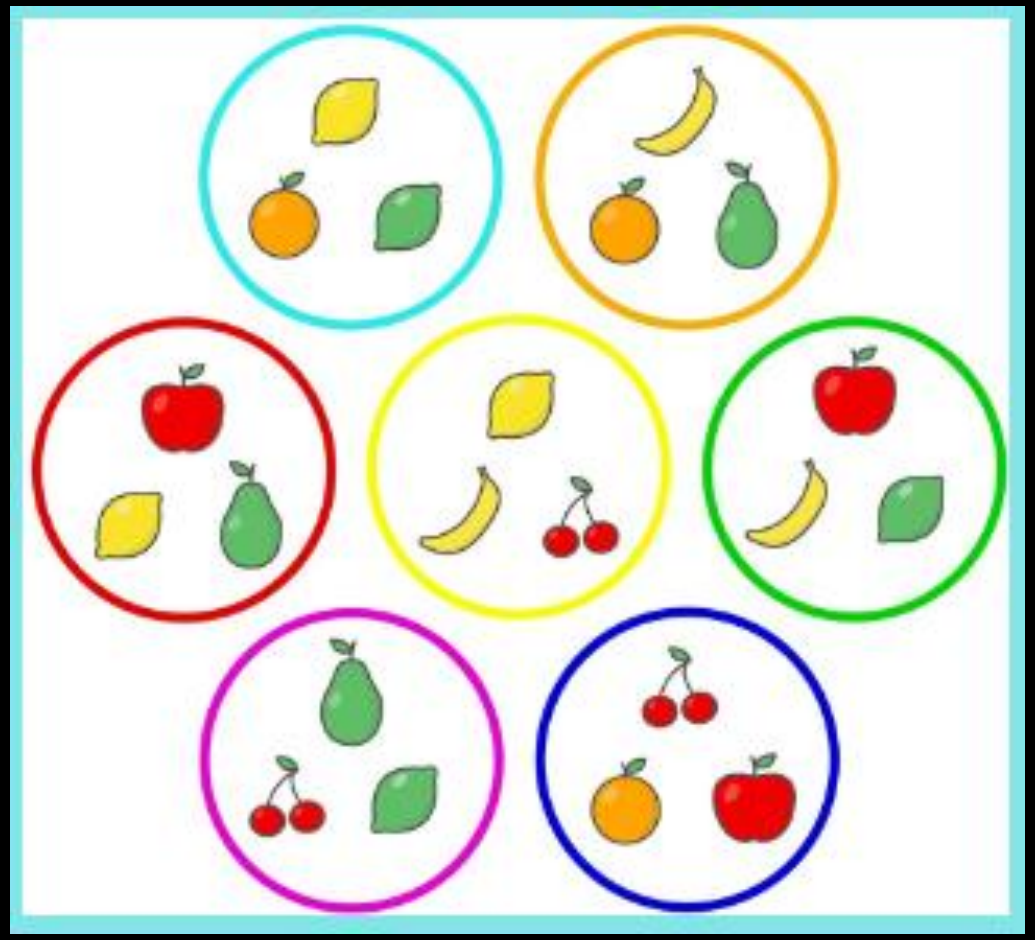
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Asmita	x	x	x				
Bernard	x			x	x		
Cathery	x					x	x
David		x		x		x	
Edward		x			x		x
Frederic			x	x			x
Gina			x		x	x	

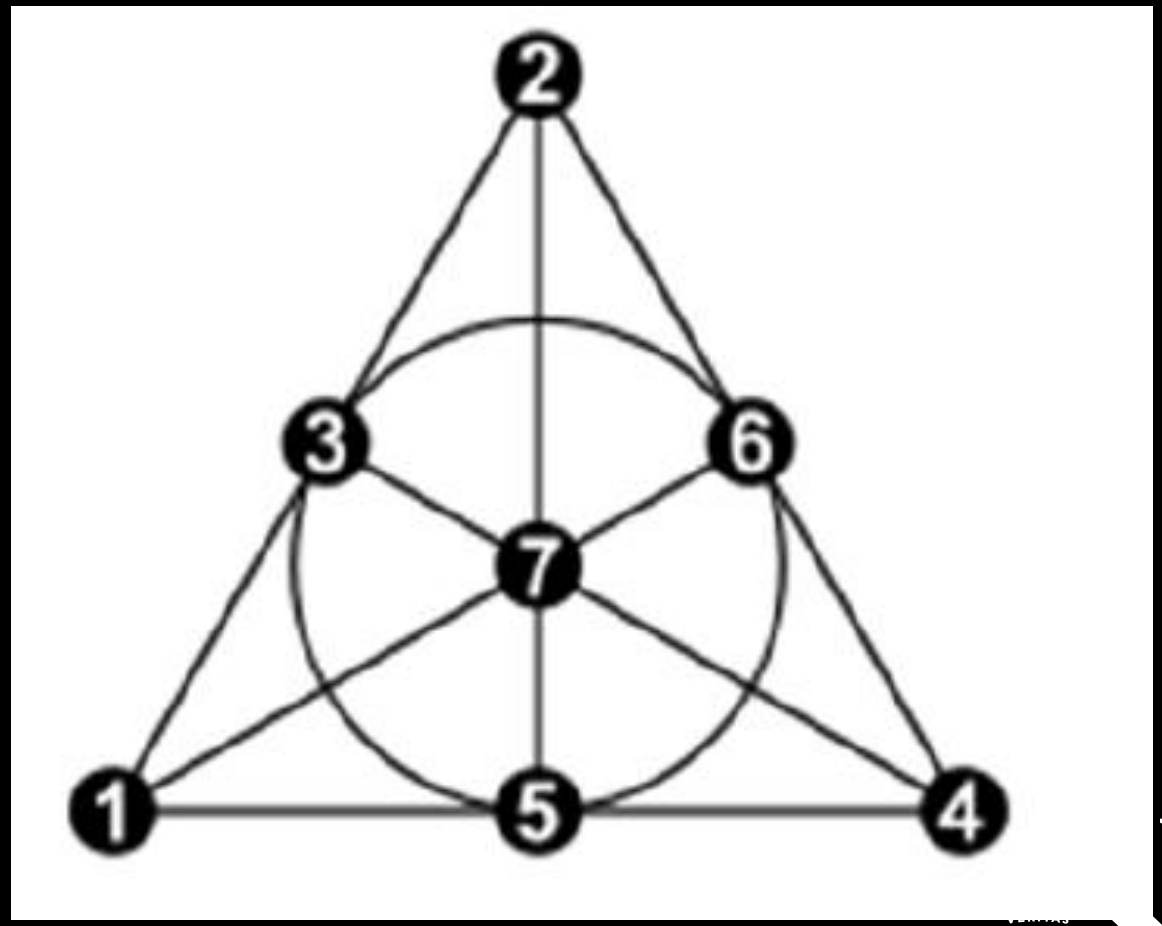
Making Connections!

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Asmita	x	x	x				
Bernard	x			x	x		
Cathery	x					x	x
David		x		x		x	
Edward		x			x		x
Frederic			x	x			x
Gina			x		x	x	



Spot-It Game (3 out of 7)





Spot-It Game (7+1 out of 7^2+7+1)

Characteristics of Great Problems

Low-floor and high-ceiling
Complex but not complicated
Highly engaging for students of ALL levels
Generalizable and extendible
Connect to other topics in the curriculum
Connect to other topics in other subjects

Conclusion: My Teaching Principles

1. My objective is not to cover the material, but to ask open-ended questions that enable students to uncover the material.

2. My goal is to create beautiful problems that enable students to develop their skills in Computational Thinking and Oral/Written Communication.

3. My focus is on the WHY, not the WHAT or HOW.

Conclusion: Mission Statement

Richard's one-sentence mission statement:

To help students discover their potential and purpose by transforming how they experience mathematics

I do this by providing authentic mathematical experiences

Conclusion: One Final Quote

True teachers use themselves as bridges over which they invite their students to cross; then, having facilitated their crossing, joyfully collapse, encouraging them to create bridges of their own.

Nikos Kazantzakis (1883-1957)

Contact Info

Richard Hoshino

Teaching Professor
Northeastern University (Vancouver Campus)

richard.hoshino@gmail.com
r.hoshino@northeastern.edu