From Contexts to Competencies
A K-12 to Post-Secondary Viewpoint
Critical Issues in Mathematics Education

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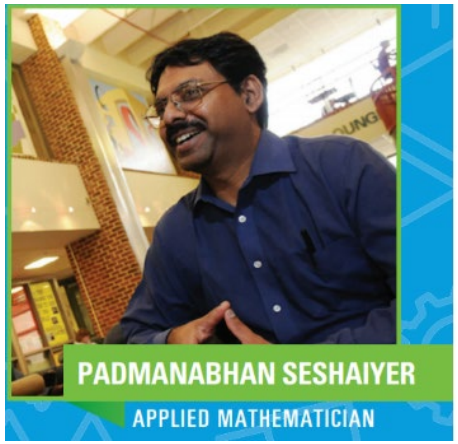
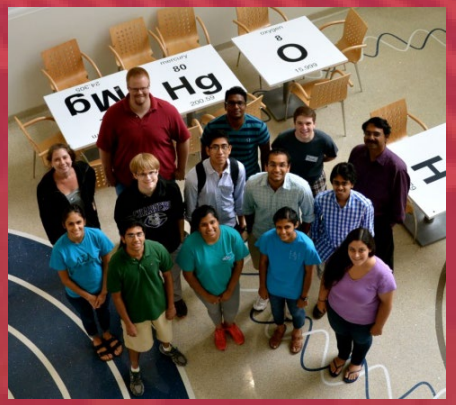


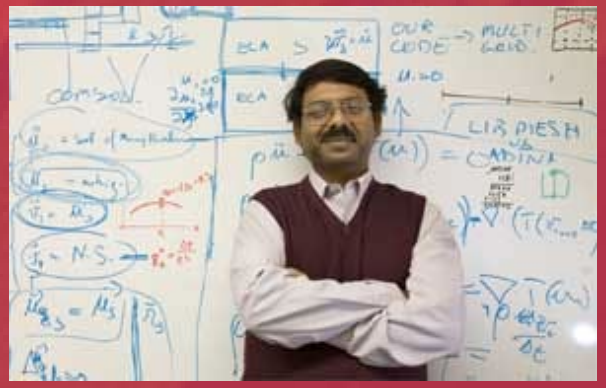
MSRI

Critical Issues in Mathematics Workshop

April 24, 2020

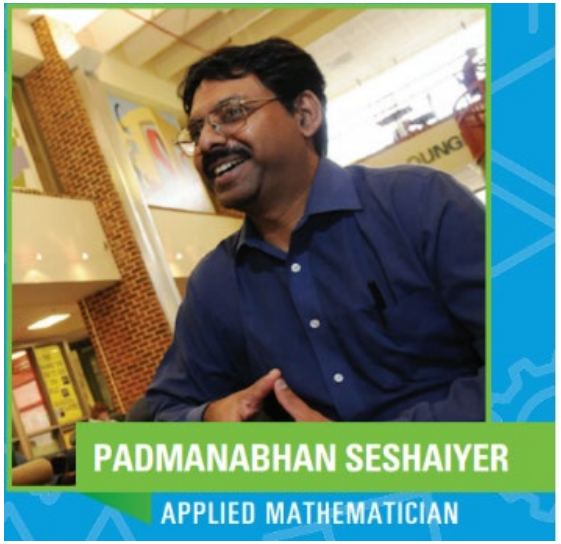
EDUCATION FOR ALL





The M in STEM

TEDx



https://www.youtube.com/watch?v=Ybxnfv2O3k4

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RESOURCE PERSON/ RESEARCHER

MANAGER

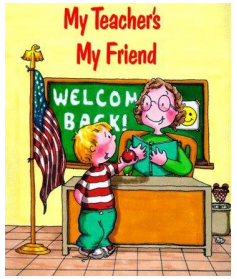
MODEL

TEACHER

FACILITATOR

EVALUATOR

COUNSELLOR/ FRIEND



THINK

TALK

REFLECT

What are some of the fundamental **competencies** needed for mathematical problem solving?

Respond at **PollEv.com/pseshaiyer217**

Text **PSESHAIYER217** to **37607**
once to join, then text your message

What are some of the fundamental **competencies** needed for mathematical problem solving?

THINK

THINK

THINK

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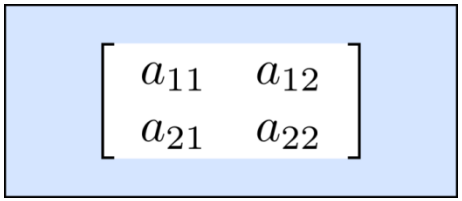
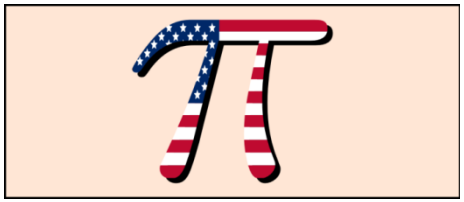
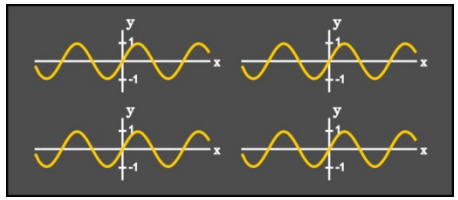
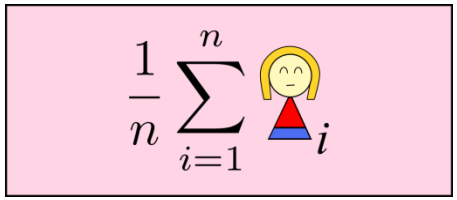
Movie Math Quiz

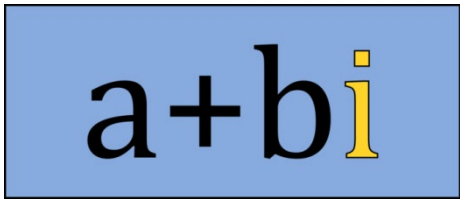
How many of the 16 movies can you find?

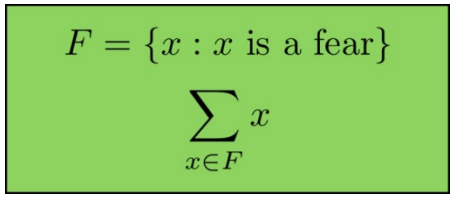


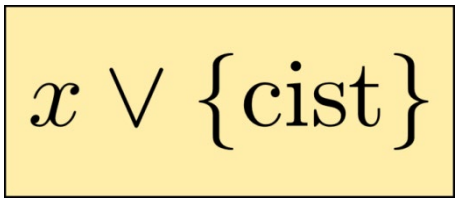


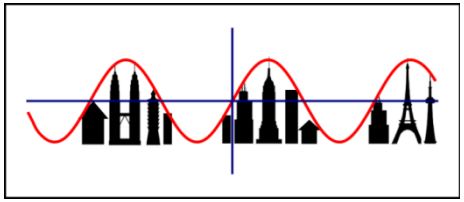


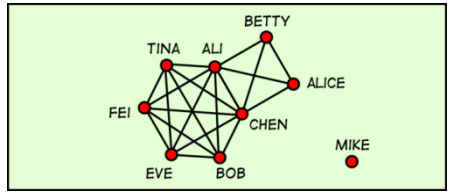


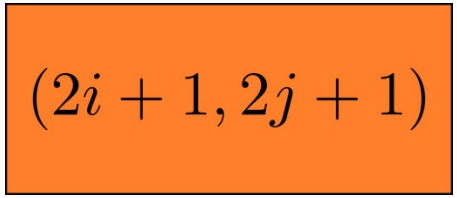


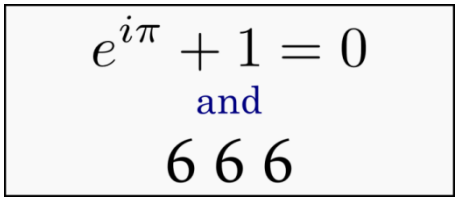


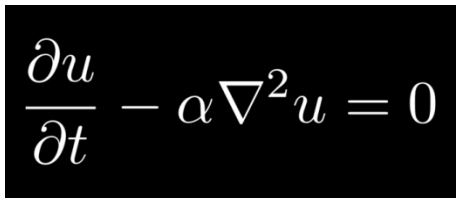


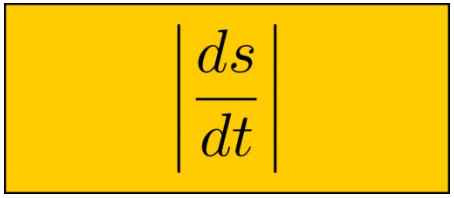












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Movie Math Quiz

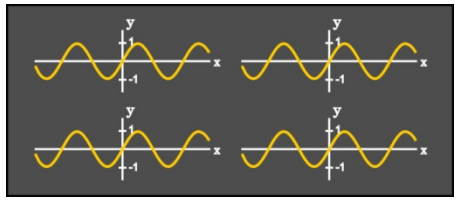
How many of the 16 movies can you find?

MATRIX

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

AMERICAN PI

THE SIGNS



MEAN GIRLS

$$\frac{1}{n}\sum_{i=1}^{n} i$$

GREEN MILE

1609.344 METRES

GOLDEN EYE

$$a+bi$$

SUM OF ALL FEARS

$$F = \{x : x \text{ is a fear}\}$$

$$\sum_{x \in F} x$$

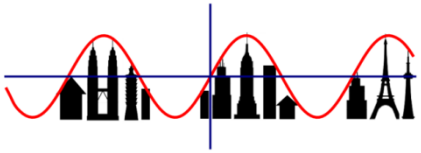
13TH FLOOR

$$\lfloor 13 \rfloor$$

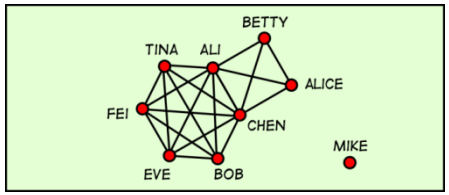
EXORCIST

$$x \vee \{\text{cist}\}$$

SIN CITY



SOCIAL NETWORK



ODD COUPLE

$$(2i+1, 2j+1)$$

BEAUTY & THE BEAST

$$e^{i\pi} + 1 = 0$$

and

6 6 6

HEAT

$$\frac{\partial u}{\partial t} - \alpha \nabla^2 u = 0$$

SPEED

$$\left| \frac{ds}{dt} \right|$$

WALL-E

2.7182818284590452...

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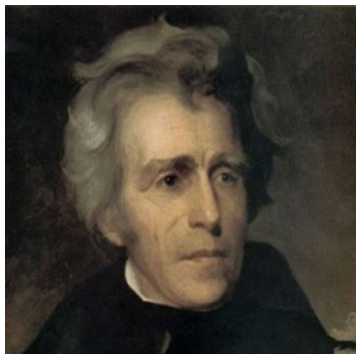
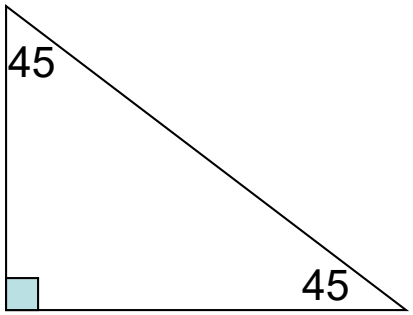
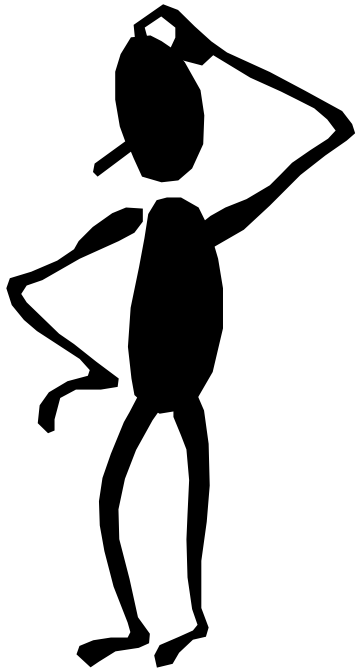
What is “e” ?







2.7182818284590452

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Fail early and often

"I have not failed, I've just found 10,000 ways that won't work"

— Thomas Edison
Inventor, Scientist

THINK

THINK

THINK

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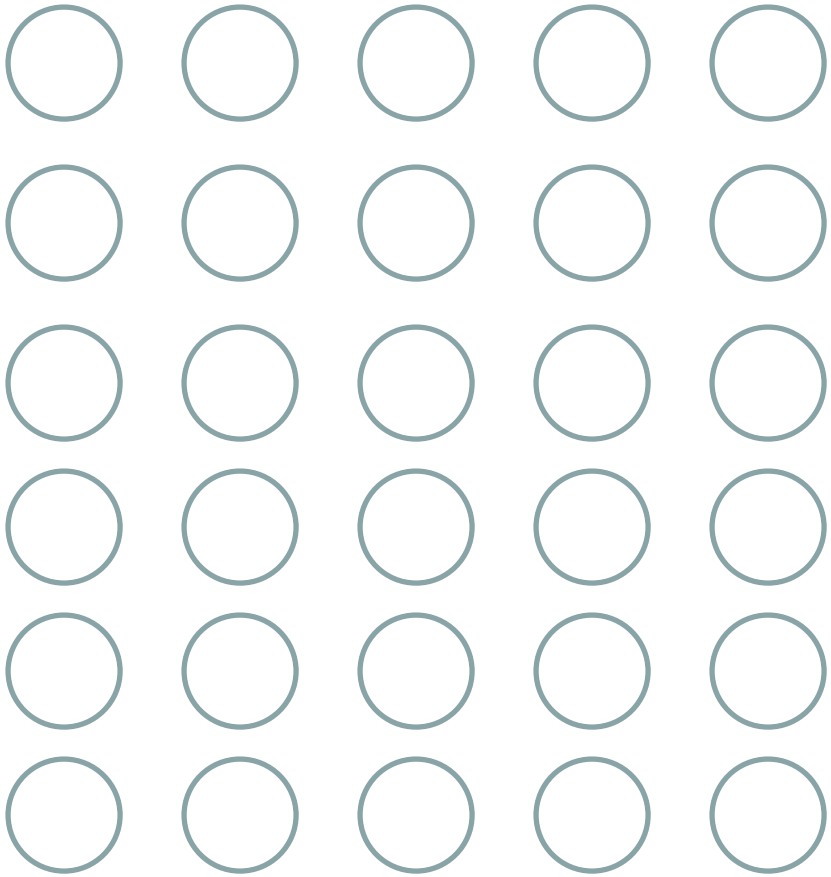
Use each circle and create an idea. Generate as many as you can (1 min)



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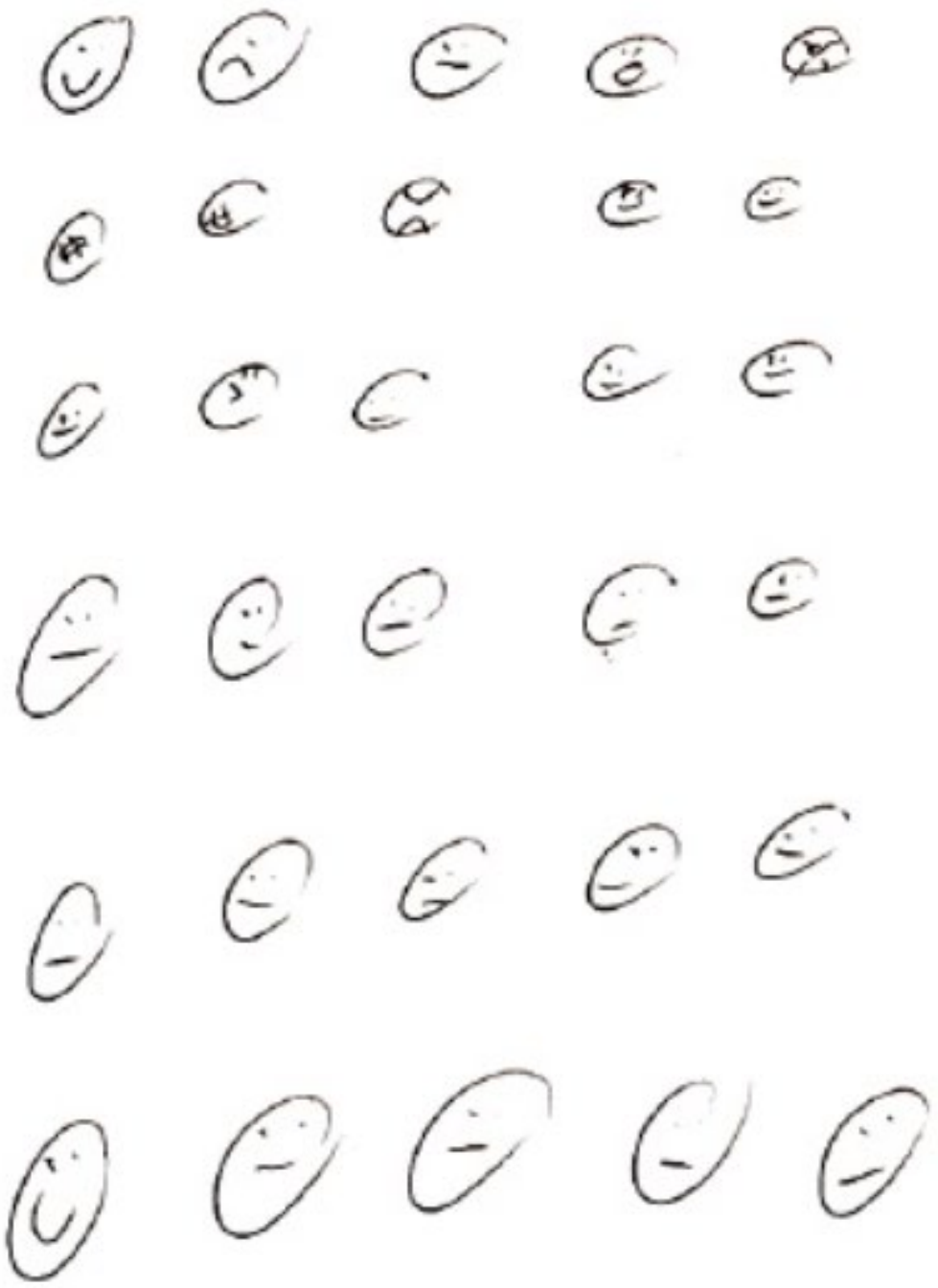

Fluency

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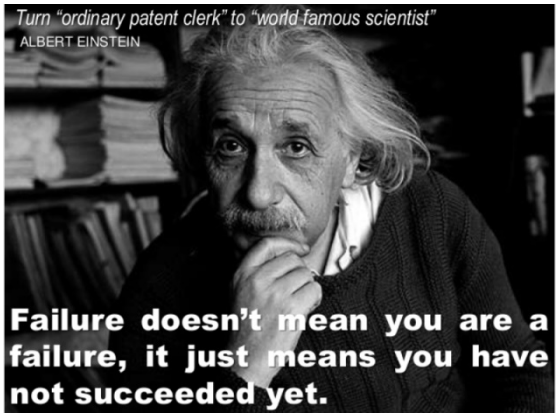
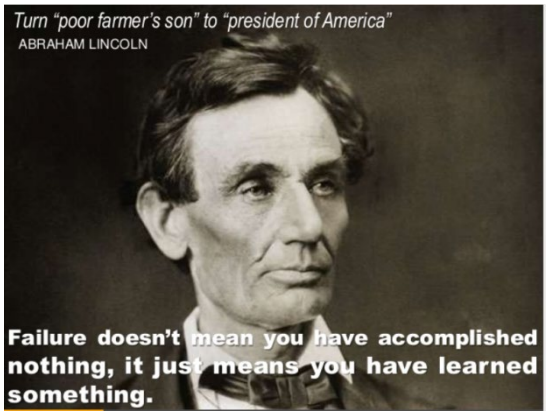
Flexibility

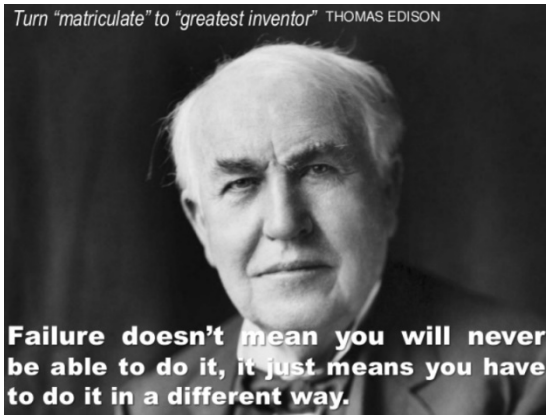
Fail Early and Fail Often

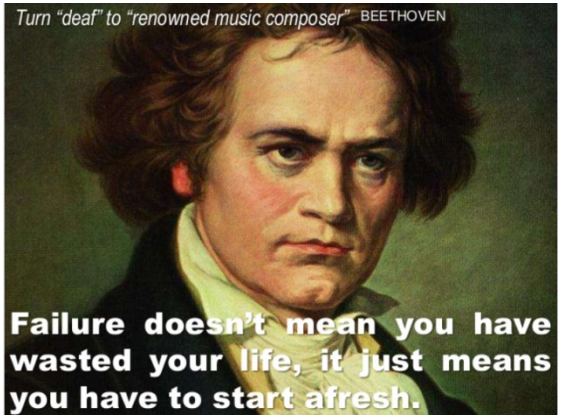
"I have not failed, I've just found 10,000 ways that won't work"

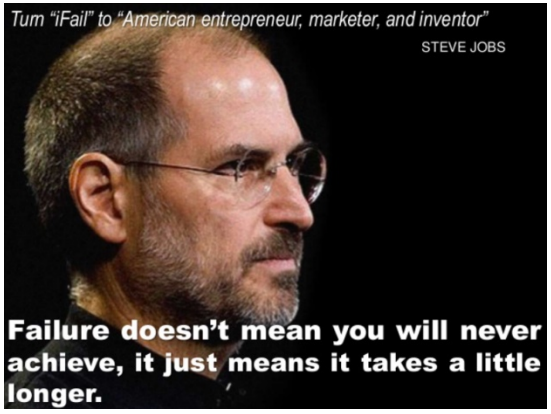
— Thomas Edison
Inventor, Scientist











THINK

NOTICE

WONDER

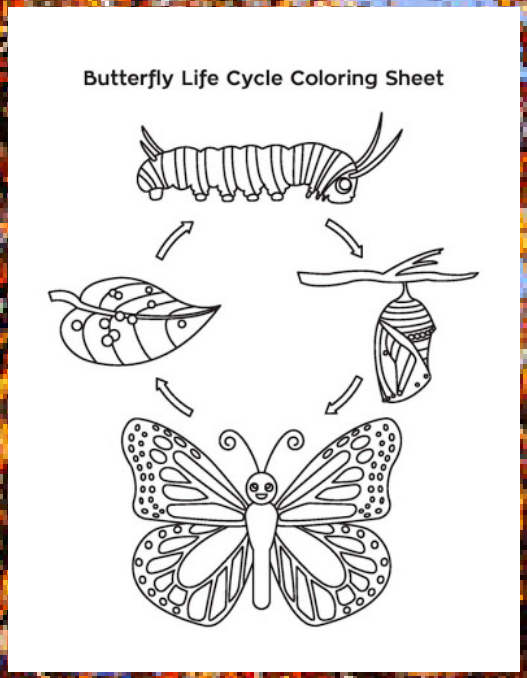
What do you NOTICE?

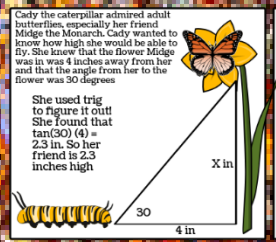
- Not symmetric
- Grouping
- Orange wings
- Color patterns
- Beauty
- Wings like tiger
- Boundaries

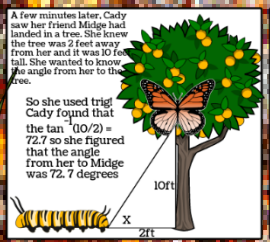
What do you WONDER?

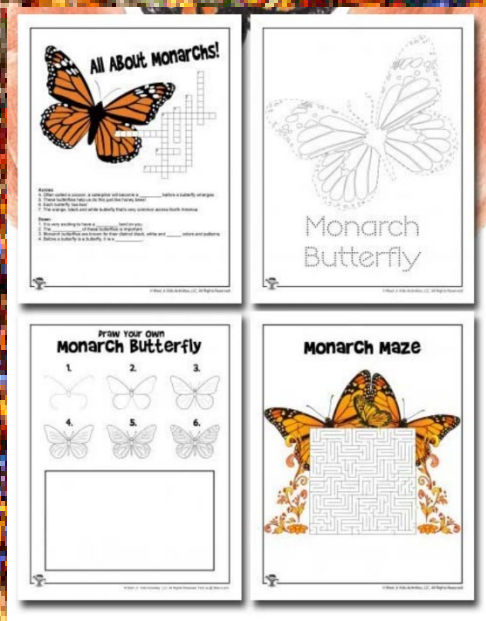
- Defense mechanism
- Where is it going
- Speed
- Fractal
- Alive
- Body weight

Monarch Butterfly Migration

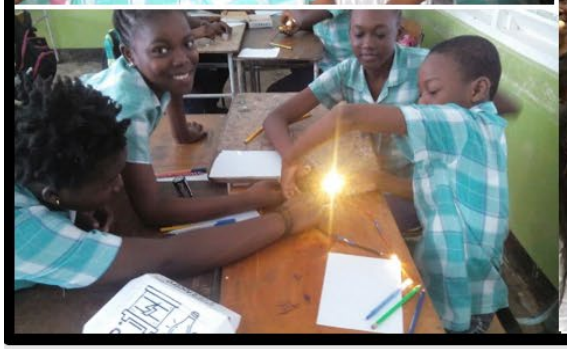








BESTREAMING
Education for all



BE-STREAMING

Suriname
South America

STEM
STEAM
STREAM

Padhu Seshaiyer

https://www.youtube.com/watch?v=_uXf1sKiros&feature=youtu.be

We STREAM Movies

We STREAM Audios

We STREAM Videos

Let's start STREAMING Education!

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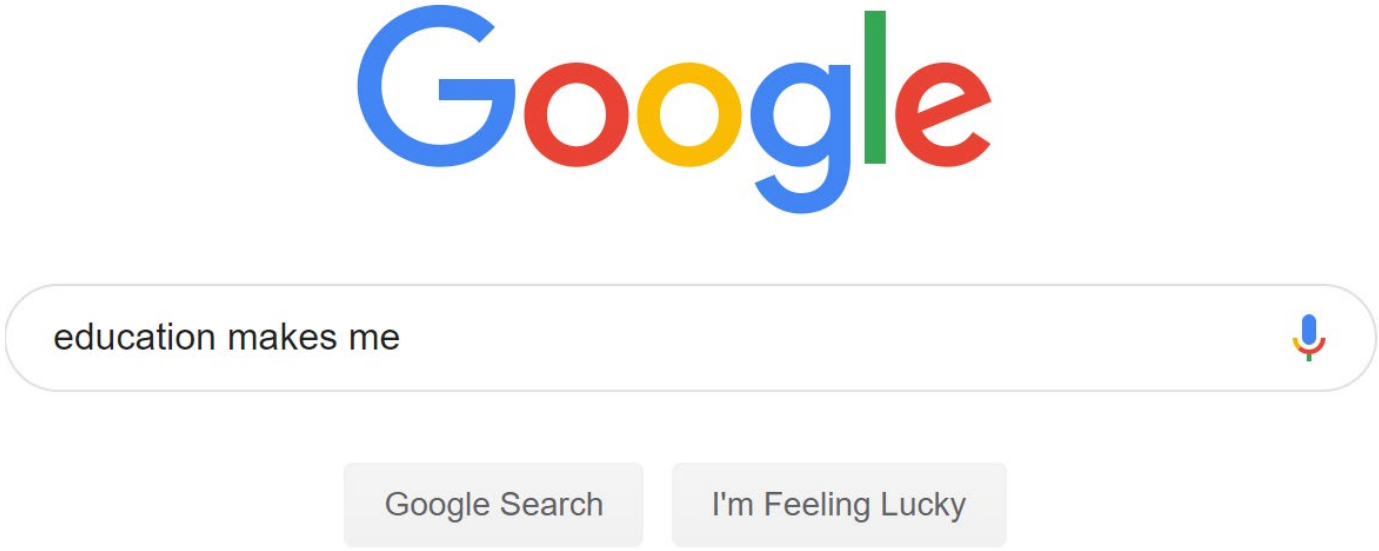
Try Typing this in Google



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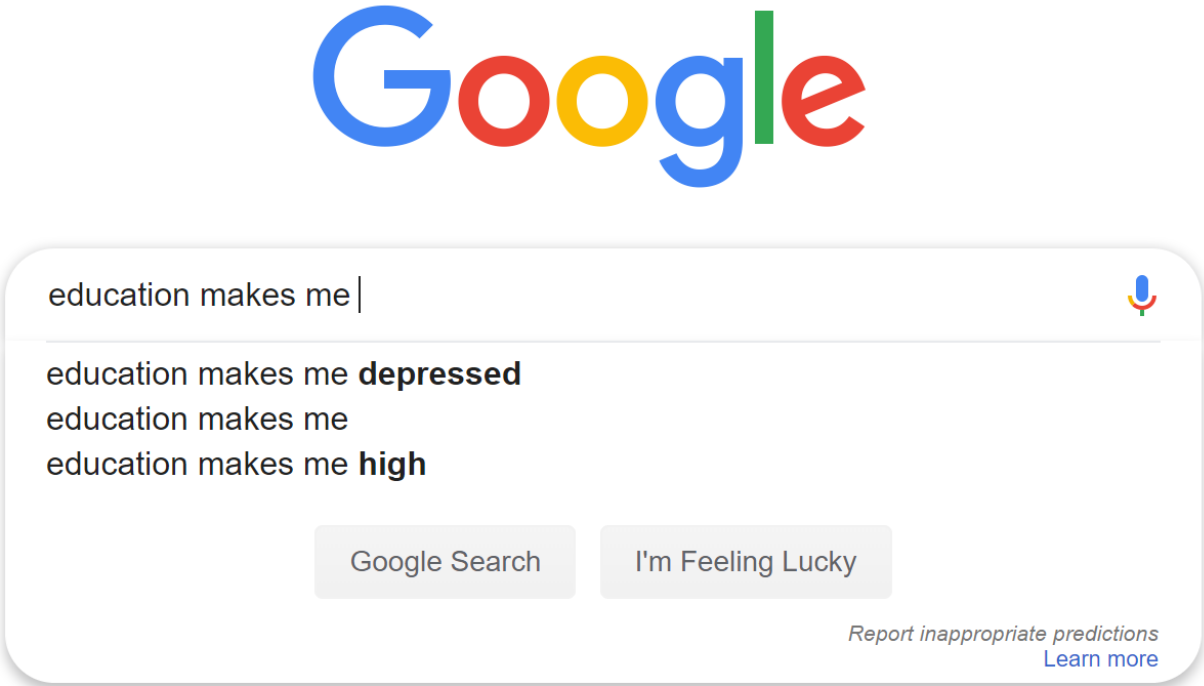
Here is what you will see…



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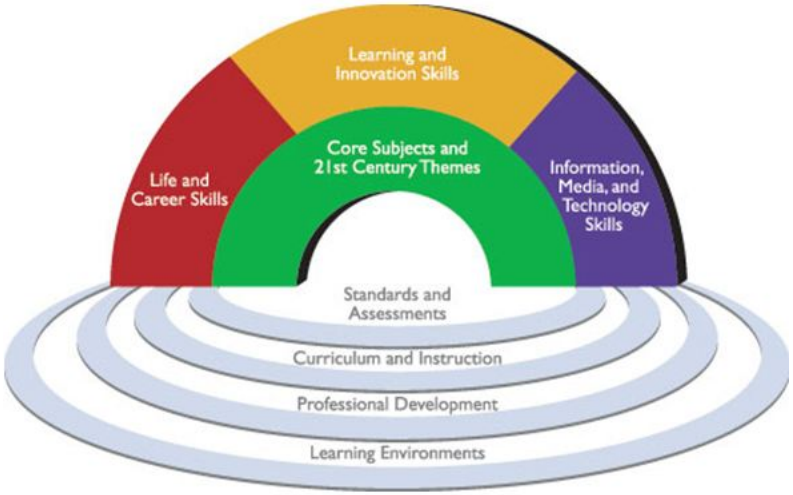
PARADIGM SHIFT

Students as Consumers

Students as Producers



Students as peer-reviewers

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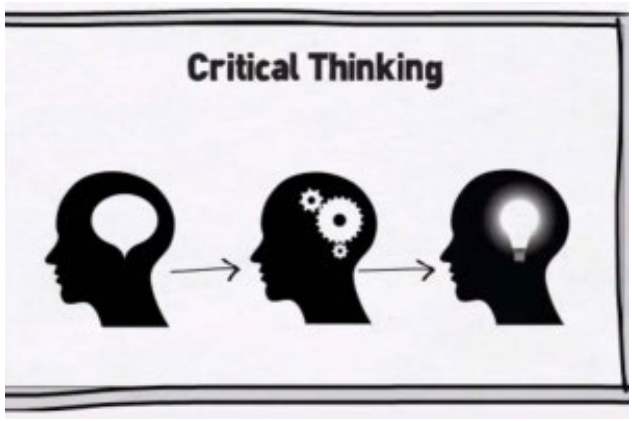
What are the 21st Century Skills?



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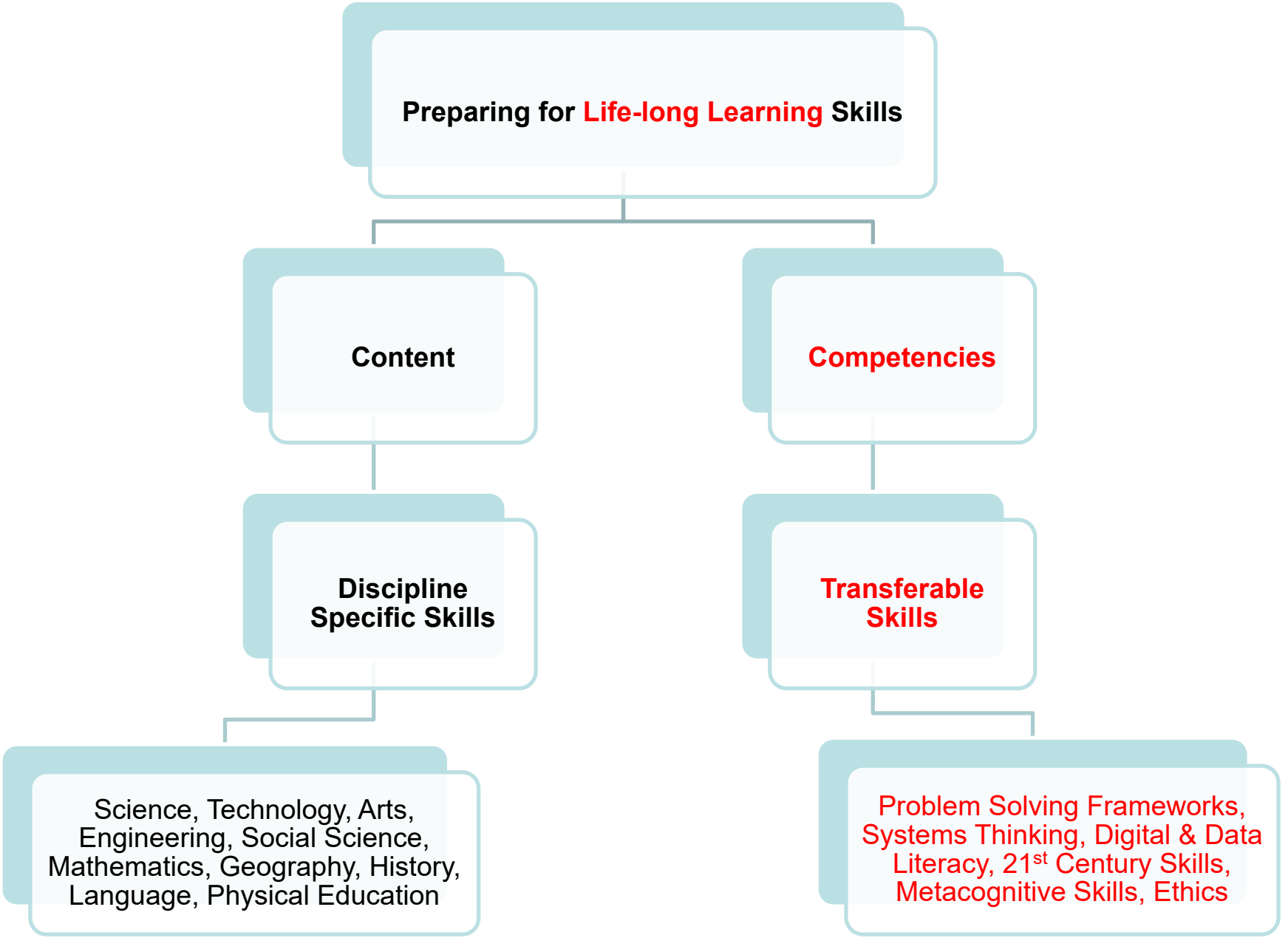
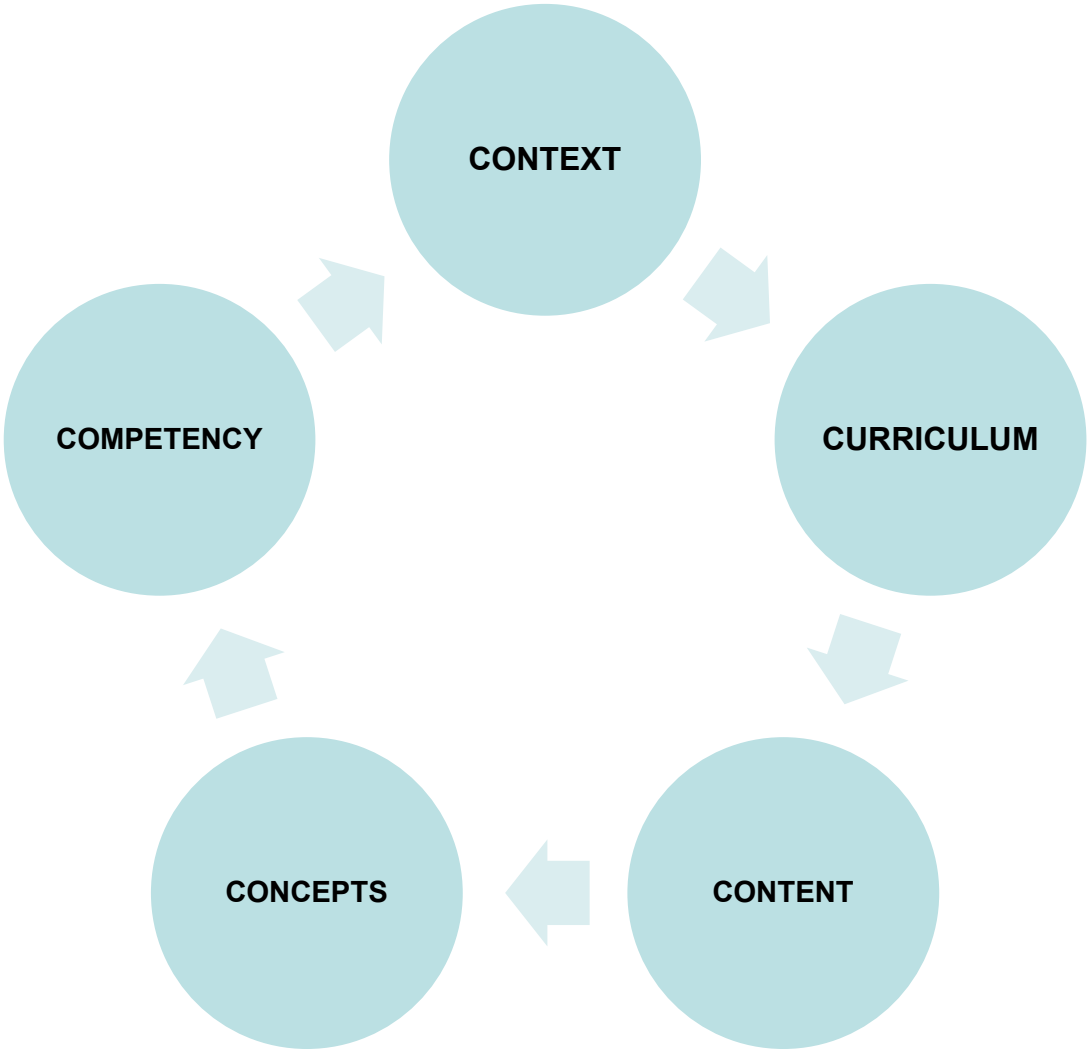


A new philosophy:
From Context to Competency



REFLECTIONS

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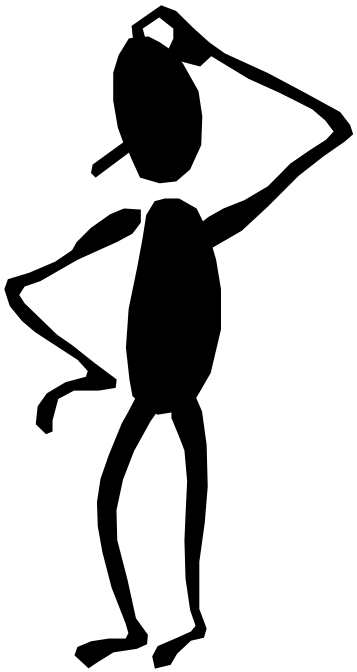
Modeling Division

$$4 \div \frac{1}{2}$$

$$\frac{4}{1/2}$$

Flip and Multiply

$$4 \times \frac{2}{1}$$



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Modeling Division

$$4 \div \frac{1}{2}$$

$$\frac{4}{\frac{1}{2}}$$

$$\frac{4}{\frac{1}{2}} \times \frac{\frac{2}{1}}{\frac{2}{1}} = 4 \times \frac{2}{1} = 8$$

Multiply and Divide by it
reciprocal

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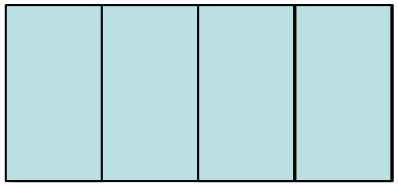
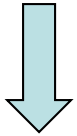
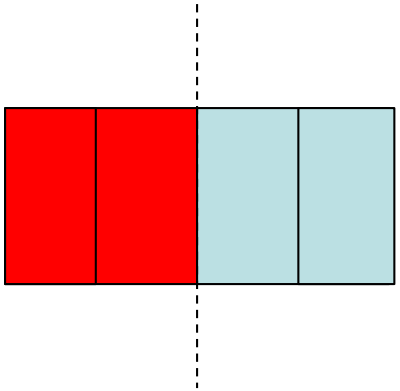
Modeling Division – Another Try

$4 \div 2$





How many twos are in 4?



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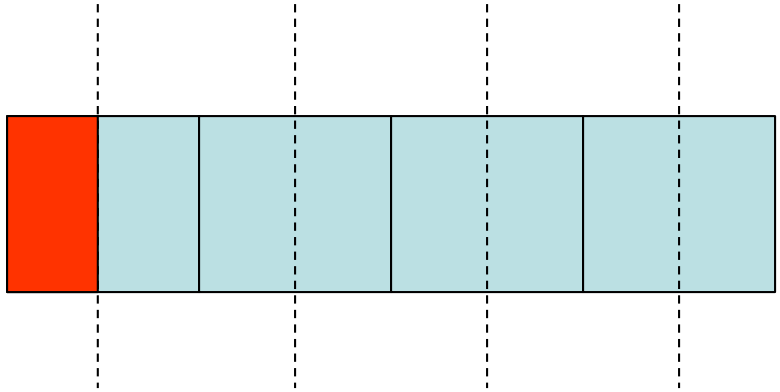
Modeling Division – Another Try

$$4 \div \frac{1}{2}$$



How many halves are in 4?

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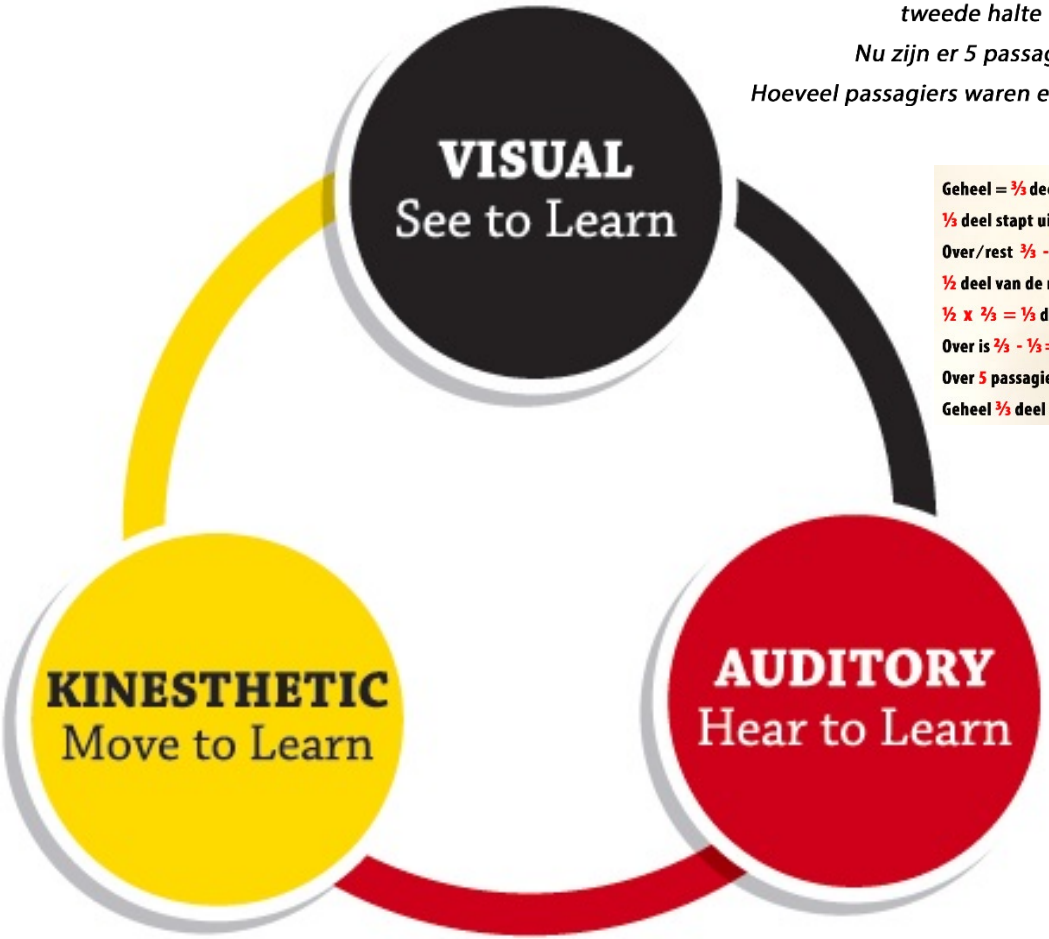
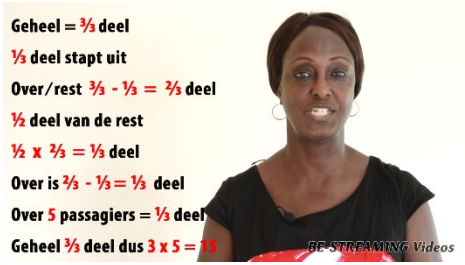
Understanding Learning Styles

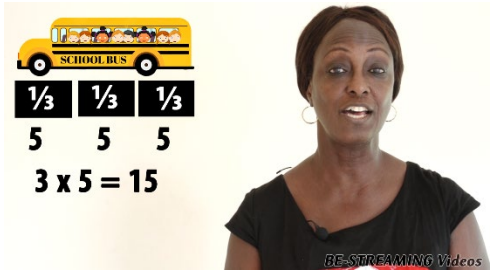


Passagiers in de Bus

⅓ deel van de passagiers stappen
bij de eerste halte uit de bus.
½ deel van de rest gaan bij
tweede halte uit de bus.
Nu zijn er 5 passagiers in de bus.
Hoeveel passagiers waren er in het begin in de bus?

BE-STREAMING Videos





Which dog grew more?

- If one dog grows from **5** kg to **8** kg and another dog grows from **3** kg to **6** kg, which dog grew more?

Which is a better investment?

Pat: Invest $300 → Receive $600

Aaron: Invest $500 → Receive $800

Why?

Why the numbers matter?

RELATIVE RISK	ABSOLUTE RISK
EATING PROCESSED MEAT INCREASES THE RISK OF COLON CANCER 18% (5.9/5.0 = 1.18)	EATING PROCESSED MEAT INCREASED ASSOCIATED COLON CANCER INCIDENCE FROM 5 PER 100 TO 5.9 PER 100 (0.9% INCREASE)
RELATIVE RISK SMOKING & CANCER IS 2300%	

RELATIVE RISK

"New wonder drug reduces heart attack risk 50%"

ABSOLUTE RISK

"New wonder drug reduced heart attacks from from 2 per 100 to 1 per 100"

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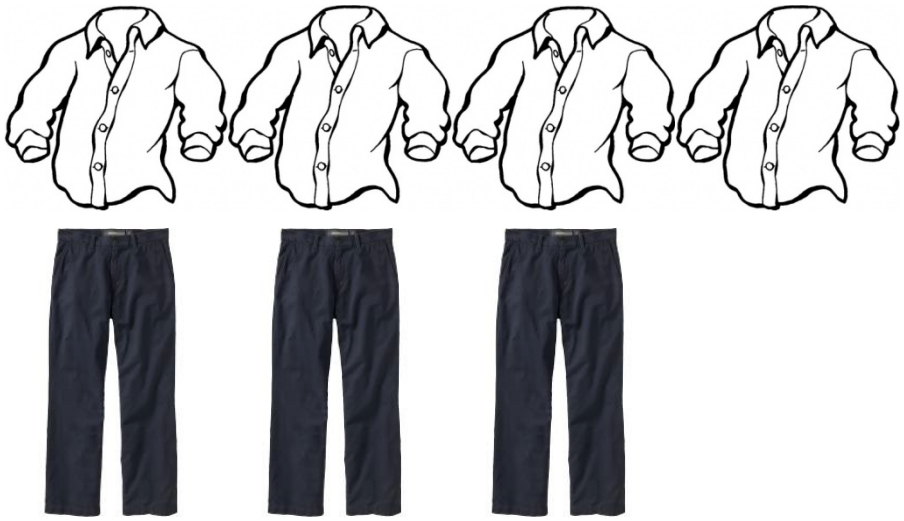
George Mason University

Finding Dress Cost

- Four shirts and three pants cost $37. Three shirts and four pants cost $33. Find the cost of one shirt.



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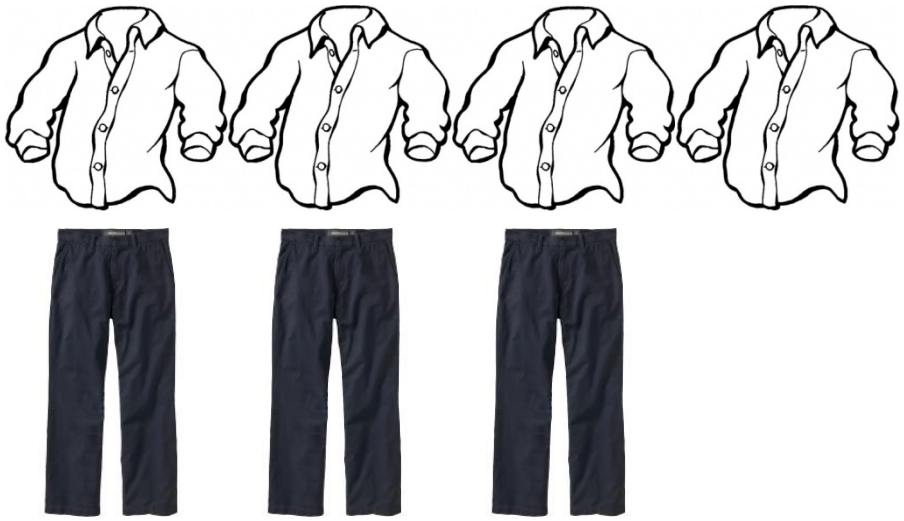
George Mason University

Finding Dress Cost

- **Four** shirts and **three** pants cost **$37**. **Three** shirts and **four** pants cost **$33**. Find the cost of one shirt.



$$4S + 3P = 37$$

$$3S + 4P = 33$$

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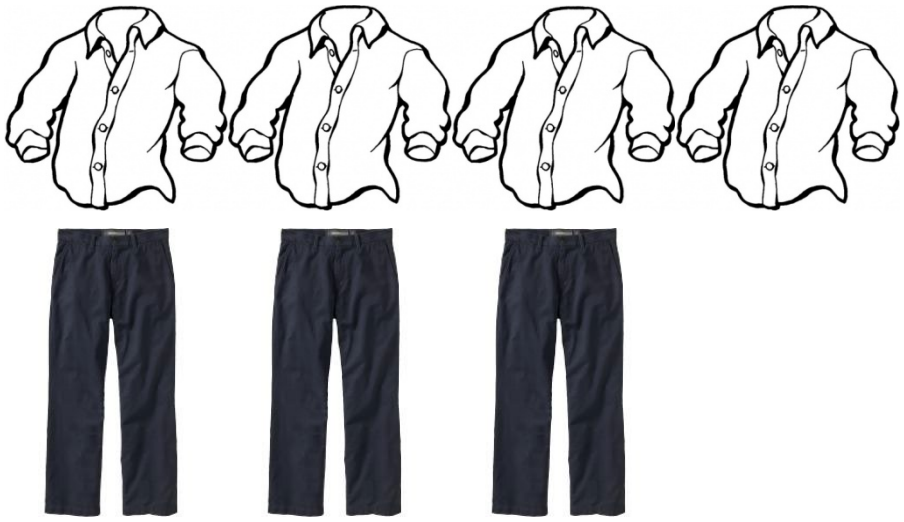
George Mason University

Finding Dress Cost

- **Four** shirts and **three** pants cost **$37**. **Three** shirts and **four** pants cost **$33**. Find the cost of one shirt.



$$4S + 3P = 37$$

$$3S + 4P = 33$$

- Substitution
- Linear Addition
- Graphing
- Matrix Inverse
- Cramer's Rule
- Gaussian Elimination
- More…

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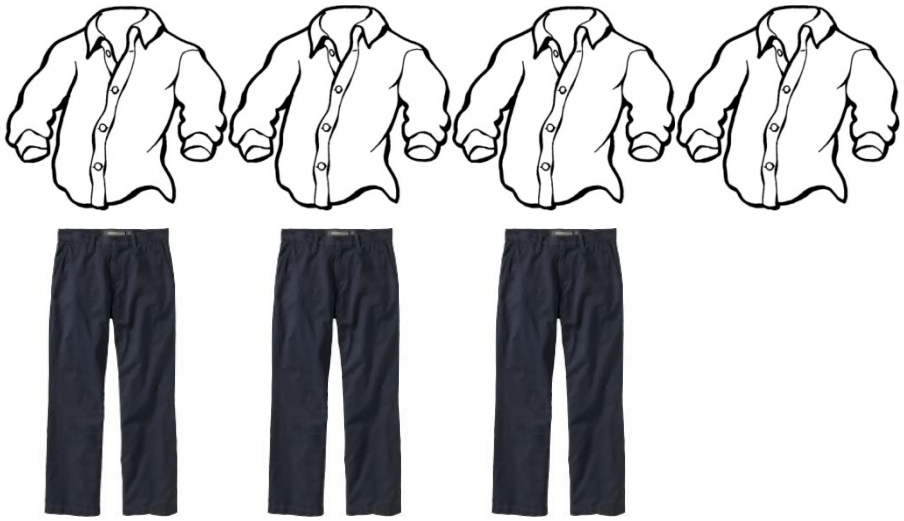
George Mason University

Modeling dress cost

- Four shirts and three pants cost $37. Three shirts and four pants cost $33. Find the cost of one shirt.



$$4S + 3P = 37$$

$$3S + 4P = 33$$

$$S - P = 4$$

$$4S + 3P = 37$$

$$5S + 2P = 41$$

$$6S + P = 45$$

$$7S = 49$$

$$S = 7$$

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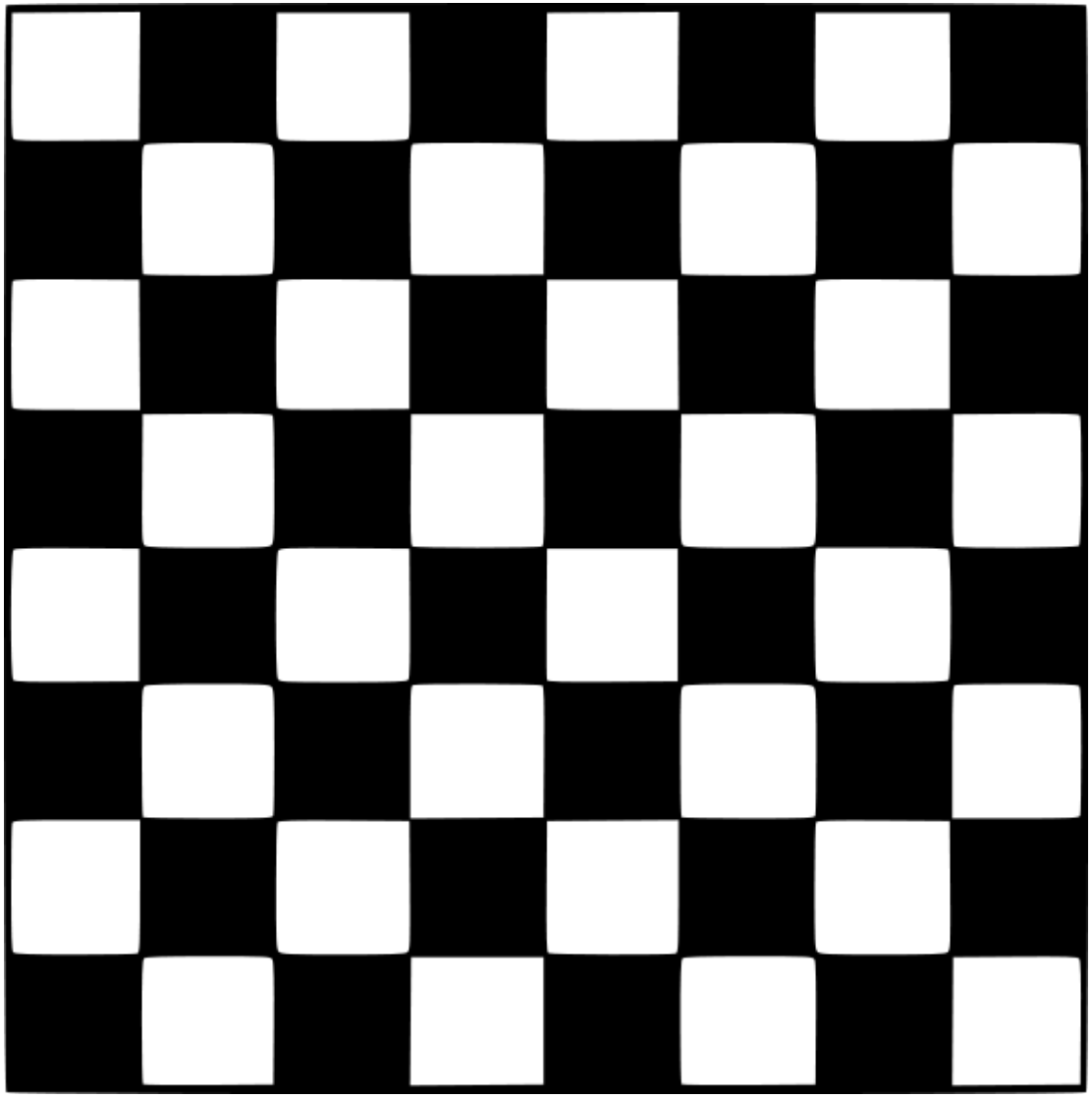
George Mason University

How many squares do you see?



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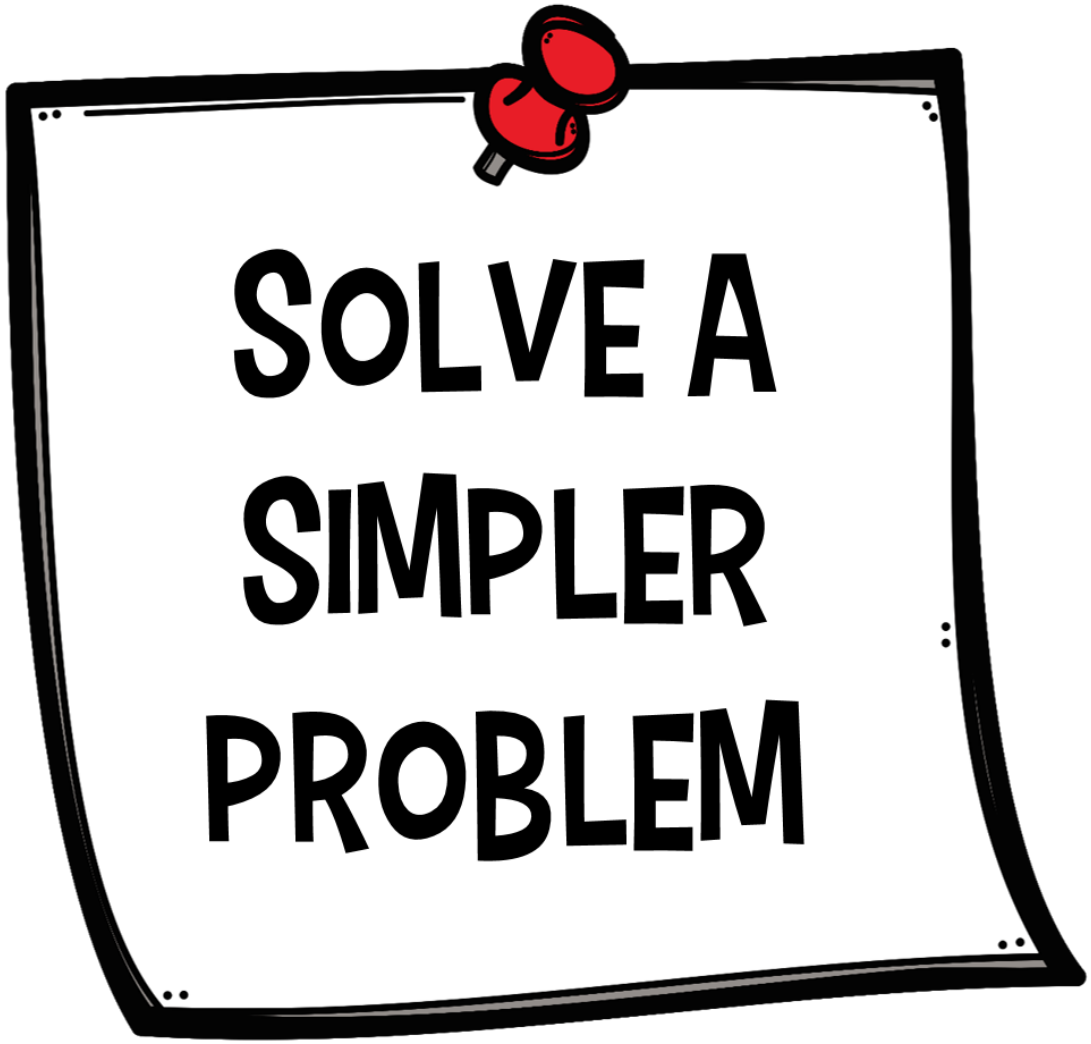
Teaching Moment



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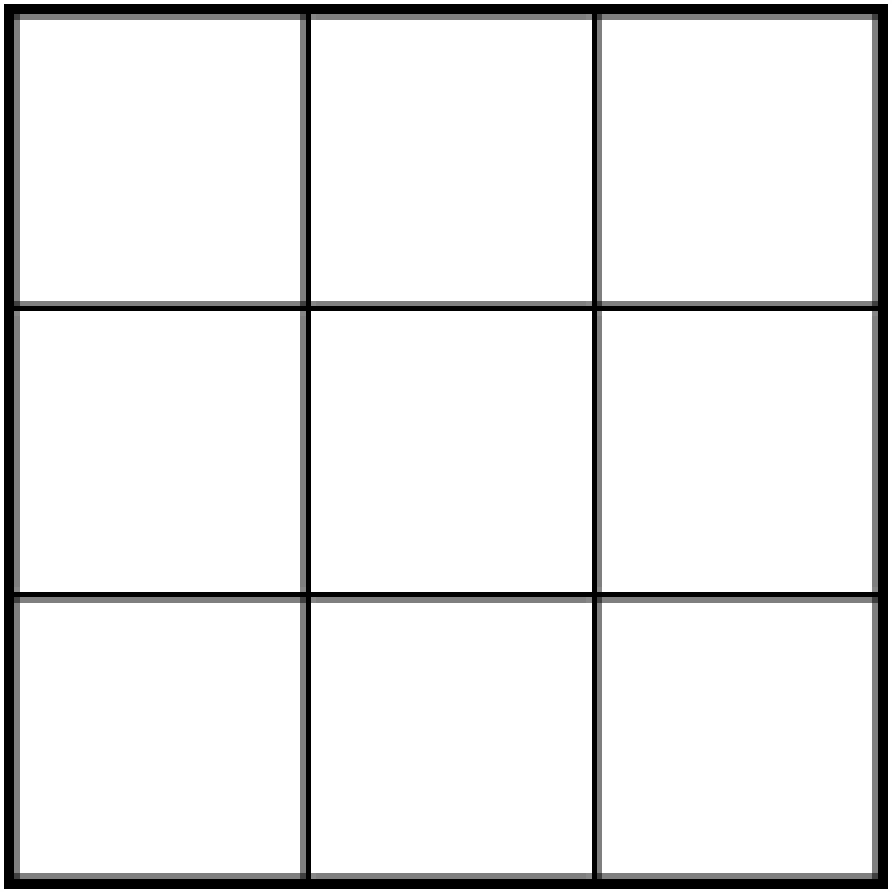
How many squares do you see?



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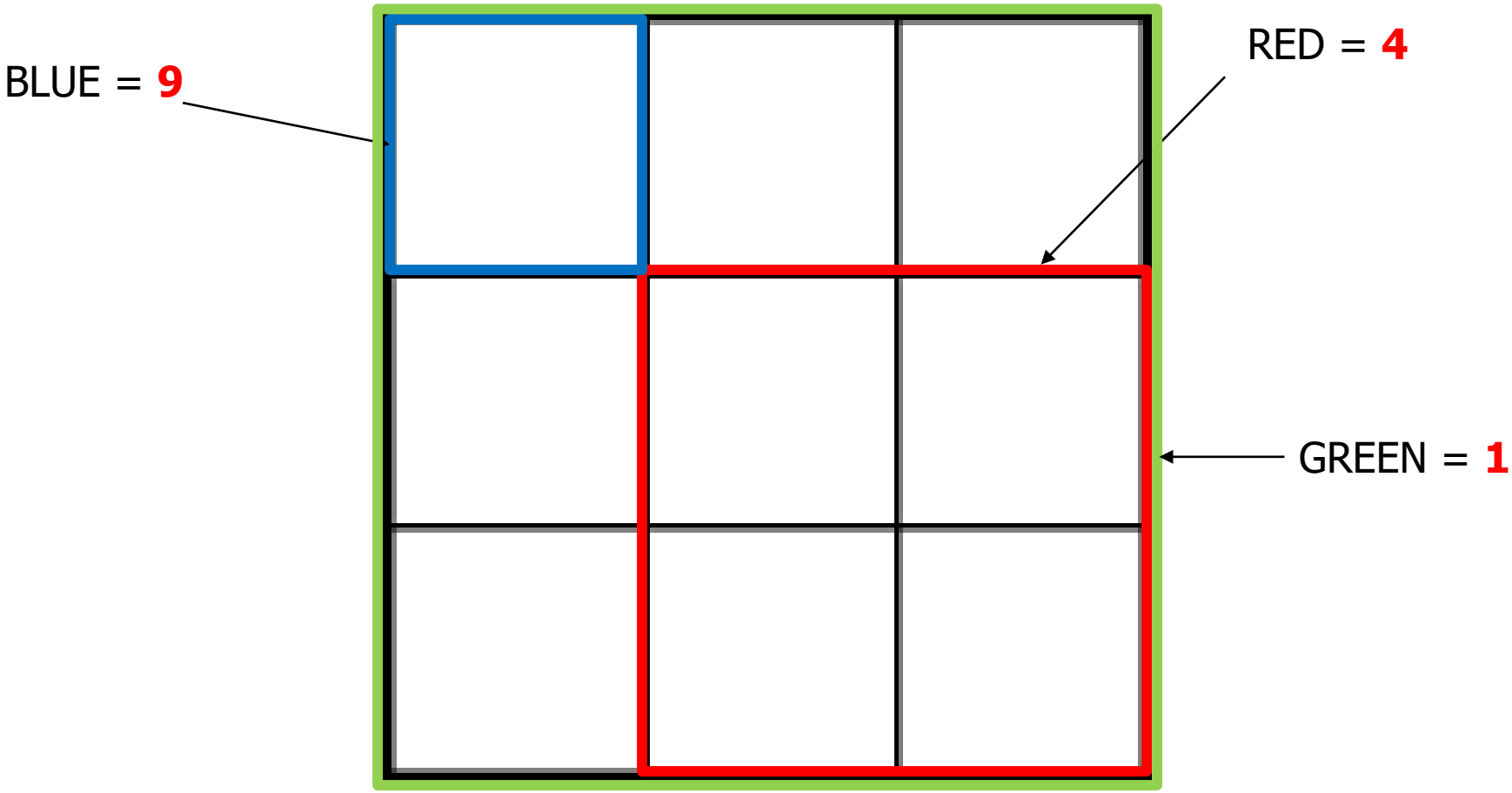
How many squares do you see?



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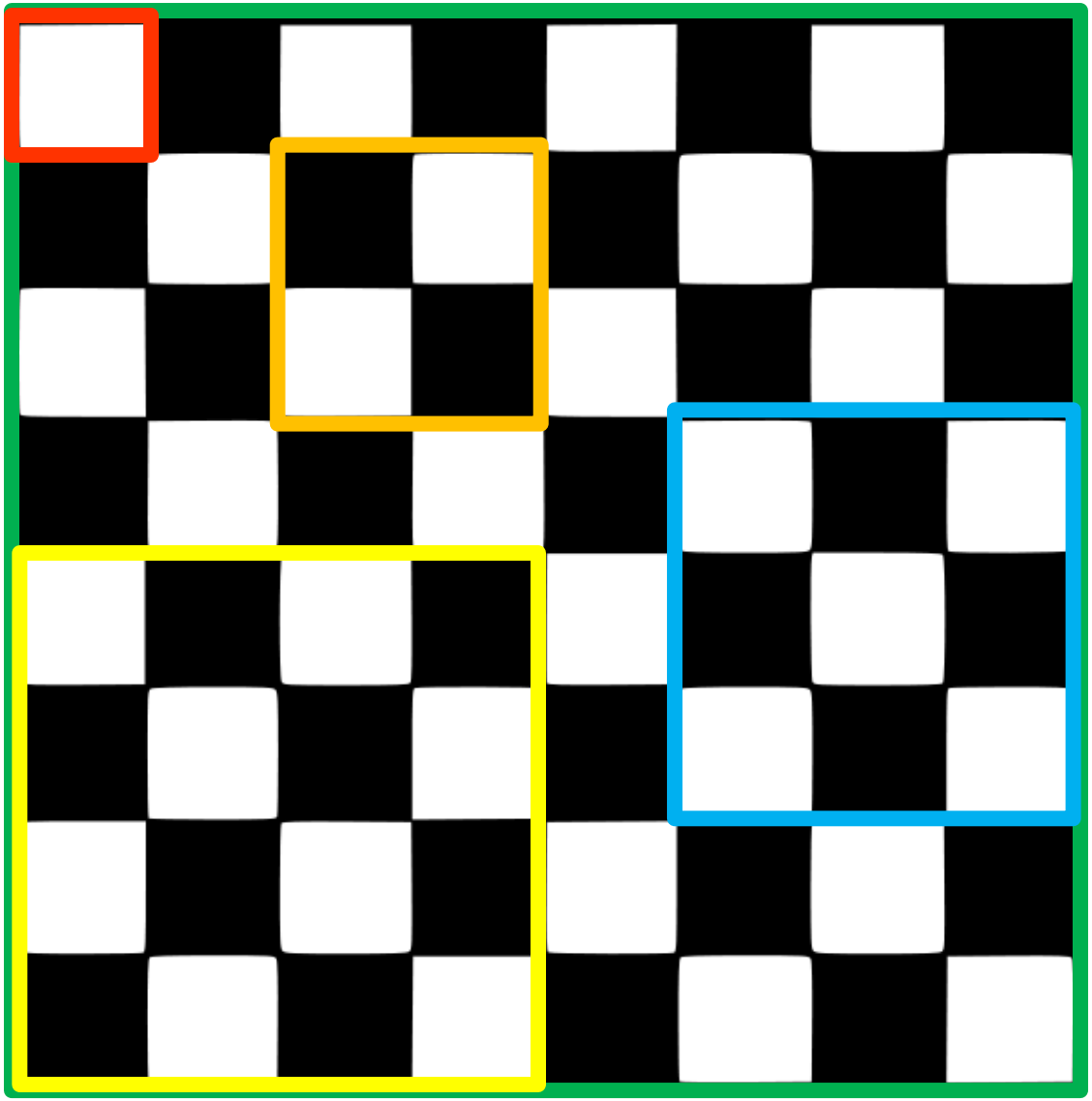

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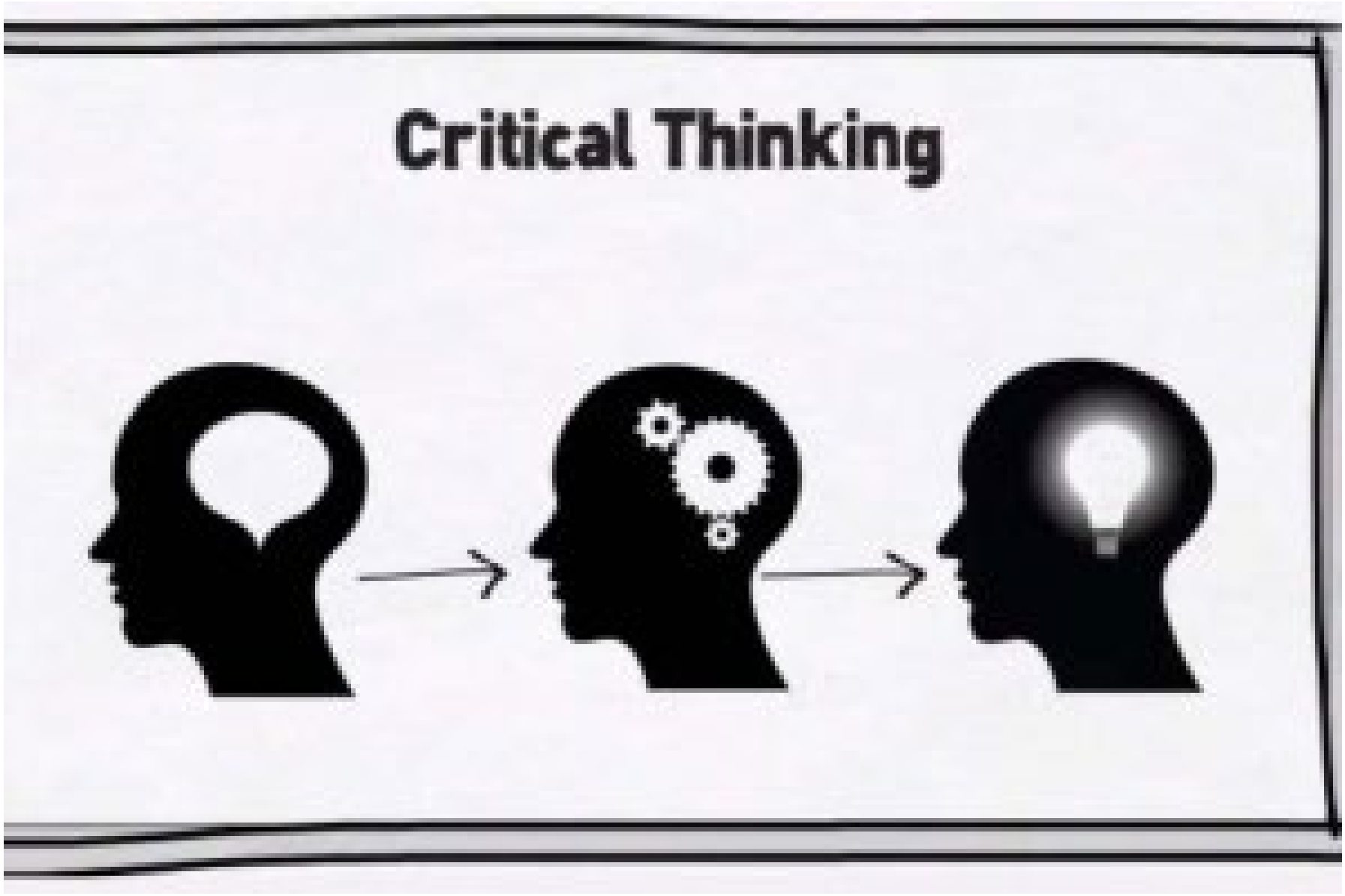

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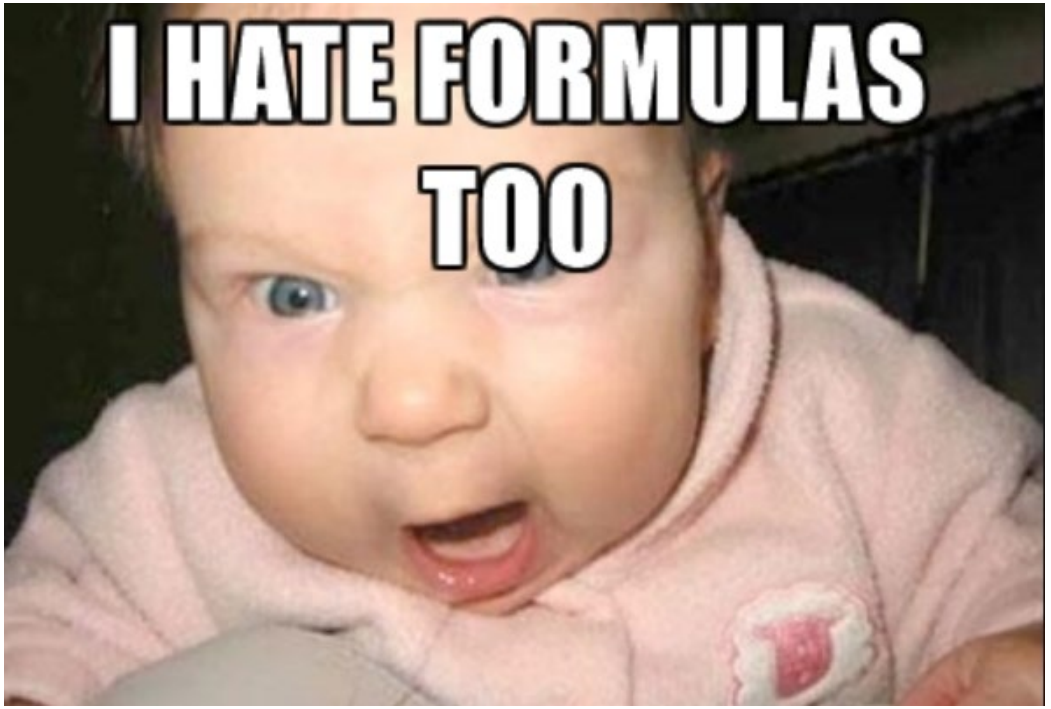

$$1^2 + 2^2 + 3^2 + \ldots\ldots + n^2 = \frac{n(n+1)(2n+1)}{6}$$

EFFECTIVE PRACTICES

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George Mason University

SINGAPORE

Teach less, Learn More

- **Teacher-directed**
- Direct Instruction
- Knowledge
- Content
- Basic Skills
- Facts and Principles
- Theory
- Curriculum
- Time-slotted
- One-size-fits-all
- Competitive
- Classroom
- Text-based
- Summative Tests
- Learning for School

- **Learner-Centered**
- Interactive exchange
- Skills
- Process
- Applied Skills
- Questions and Problems
- Practice
- Projects
- On-demand
- Personalized
- Collaborative
- Global Community
- Web-based
- Formative evaluations
- Learning for Life

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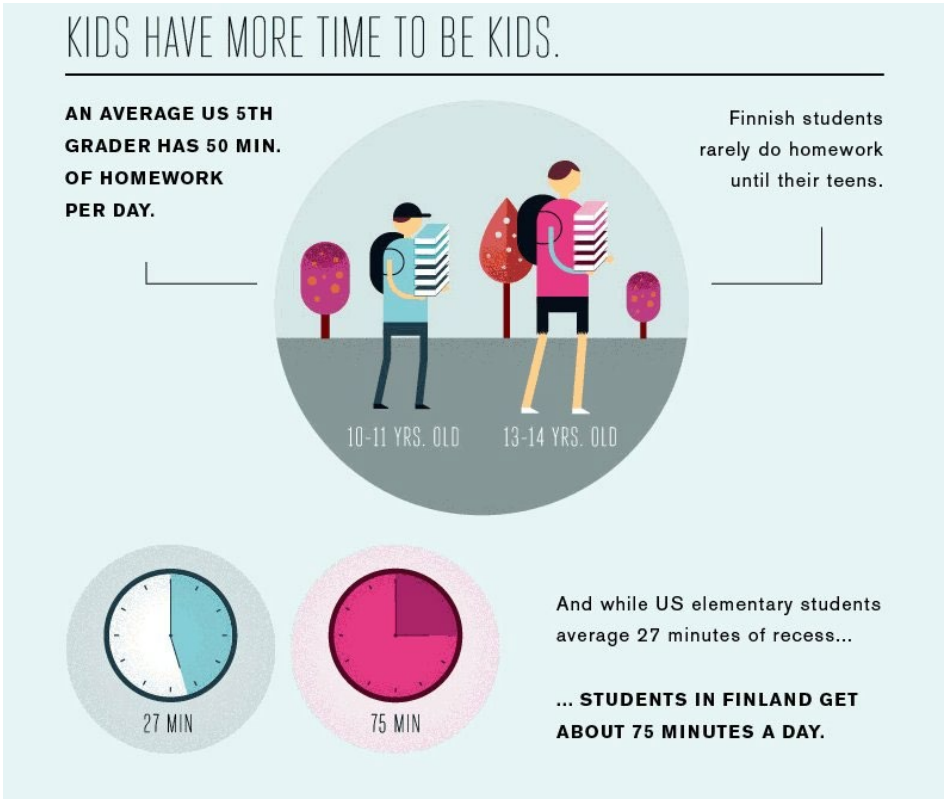
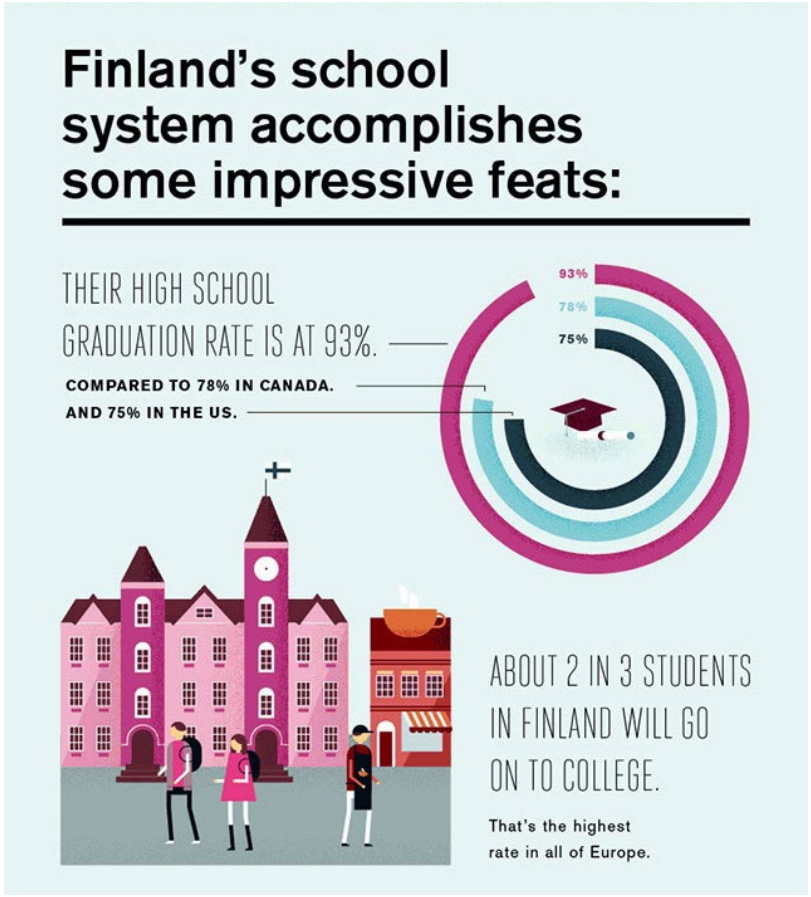
FINLAND

Learning by Doing





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JAPAN

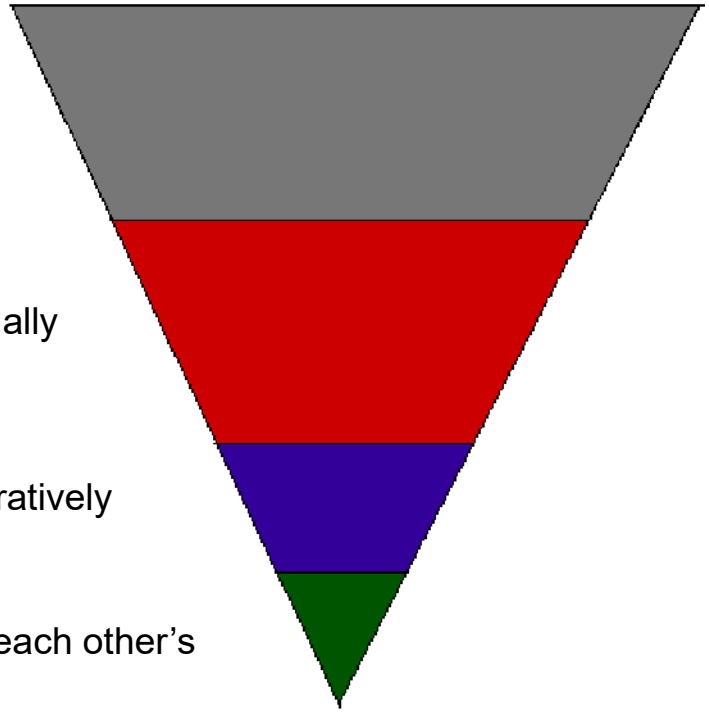
Teachers' Activities to Improve Instruction

Choose curriculum,
write curriculum,
align curriculum,
write local standards

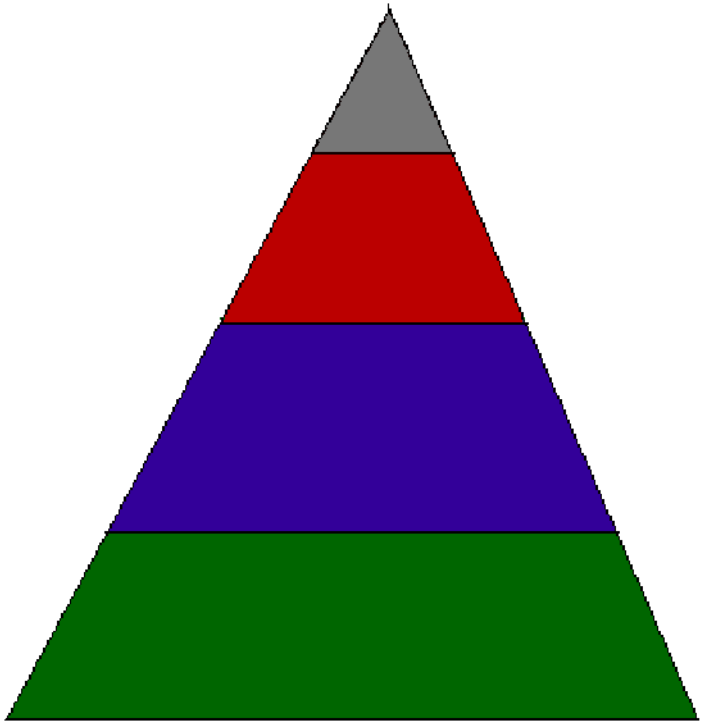
Plan lessons individually

Plan lessons collaboratively

Watch and discuss each other's
classroom lessons



U.S.



JAPAN

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Experiential Learning

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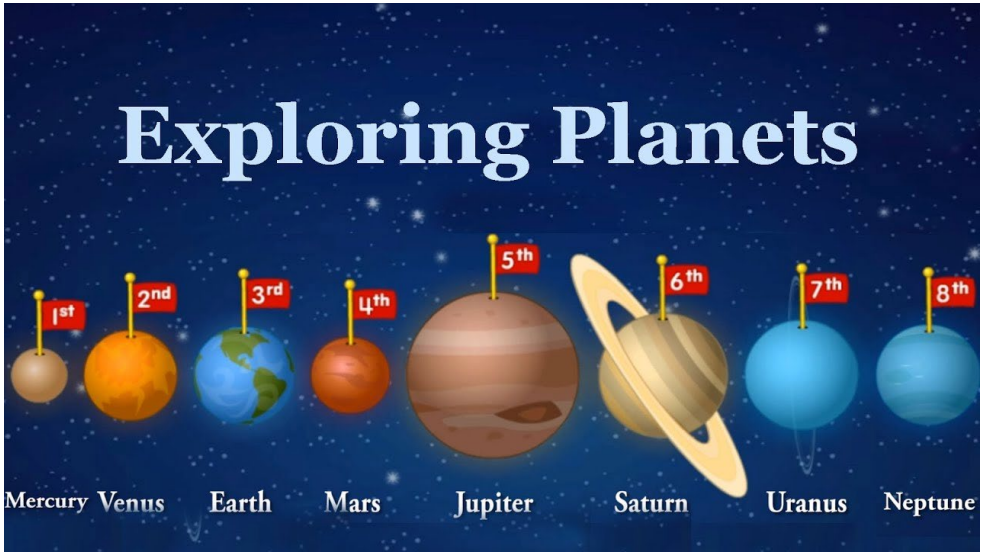
George Mason University

Innovative Learning



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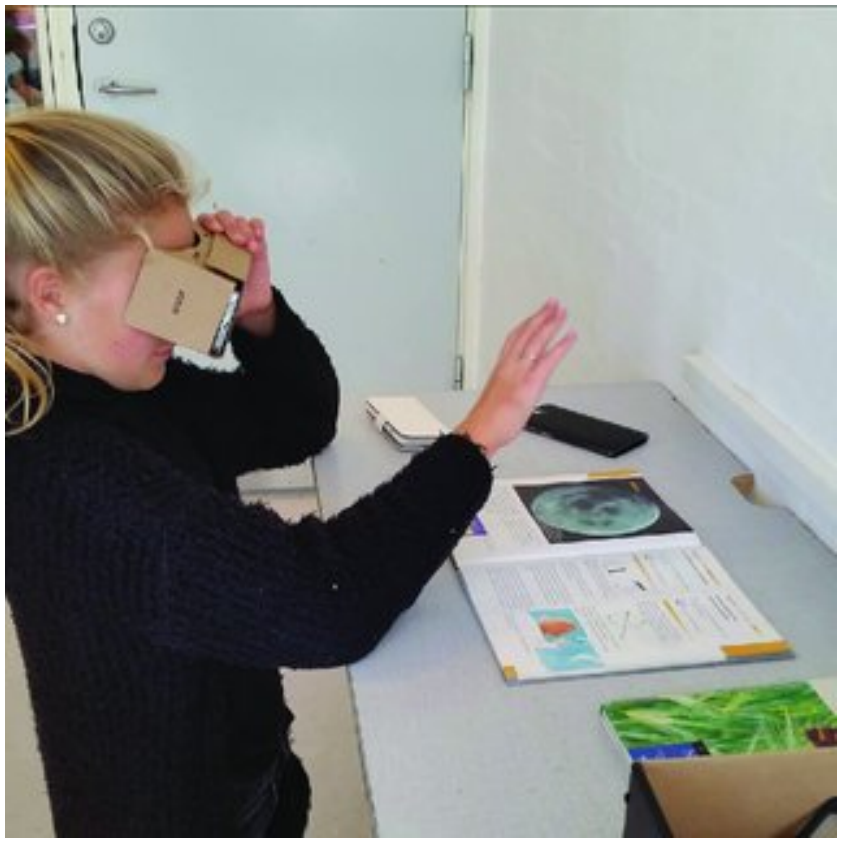
Innovative Learning



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Inquiry-based Learning

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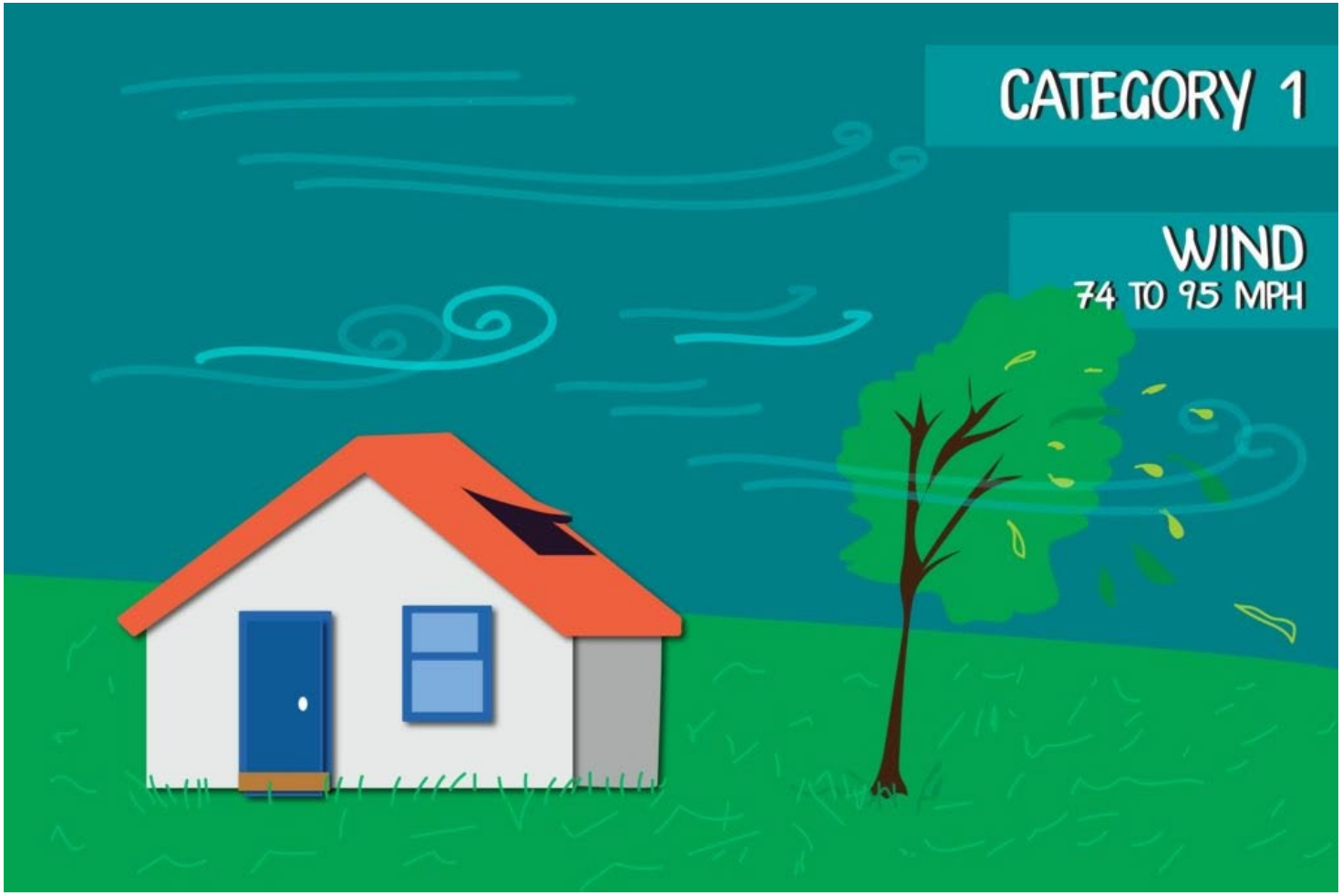
Why do roofs fly?



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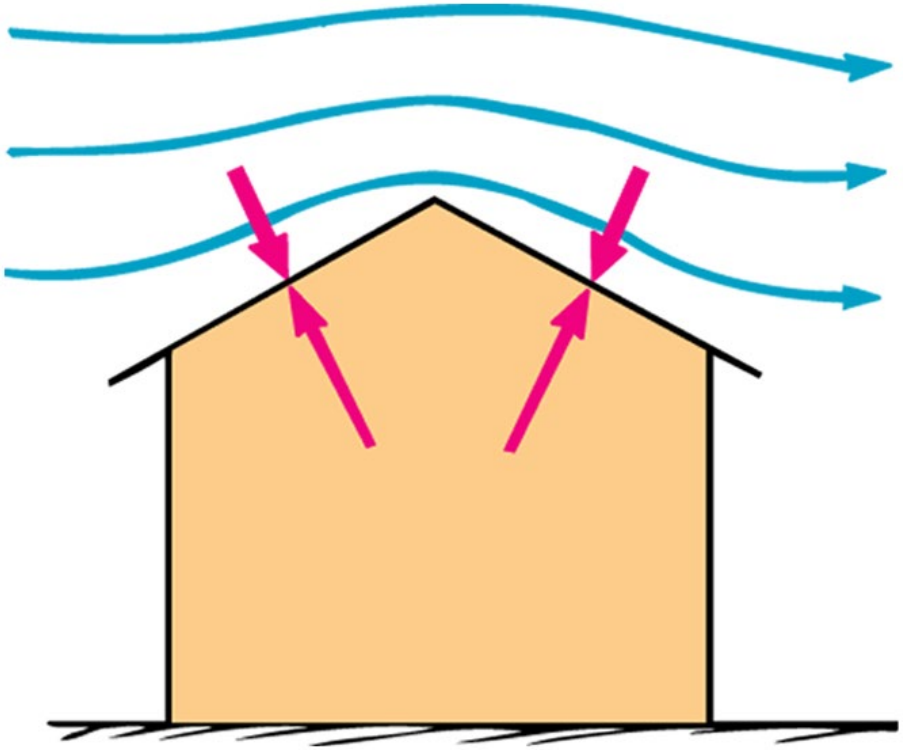
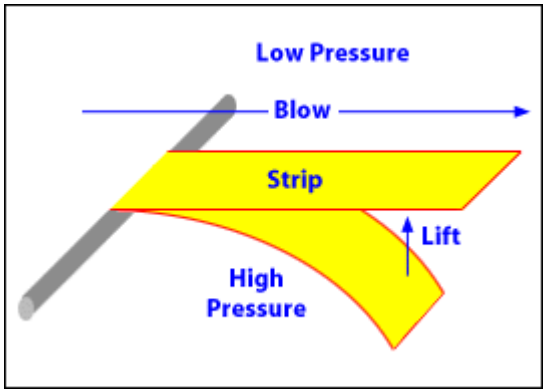
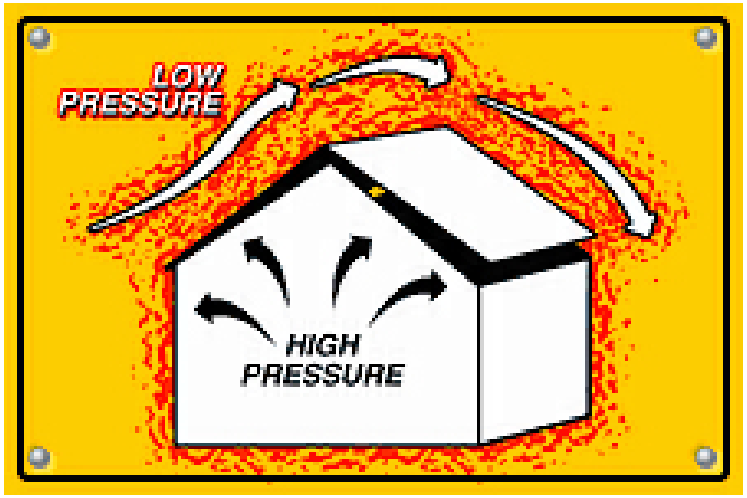
Bernoulli's Principle







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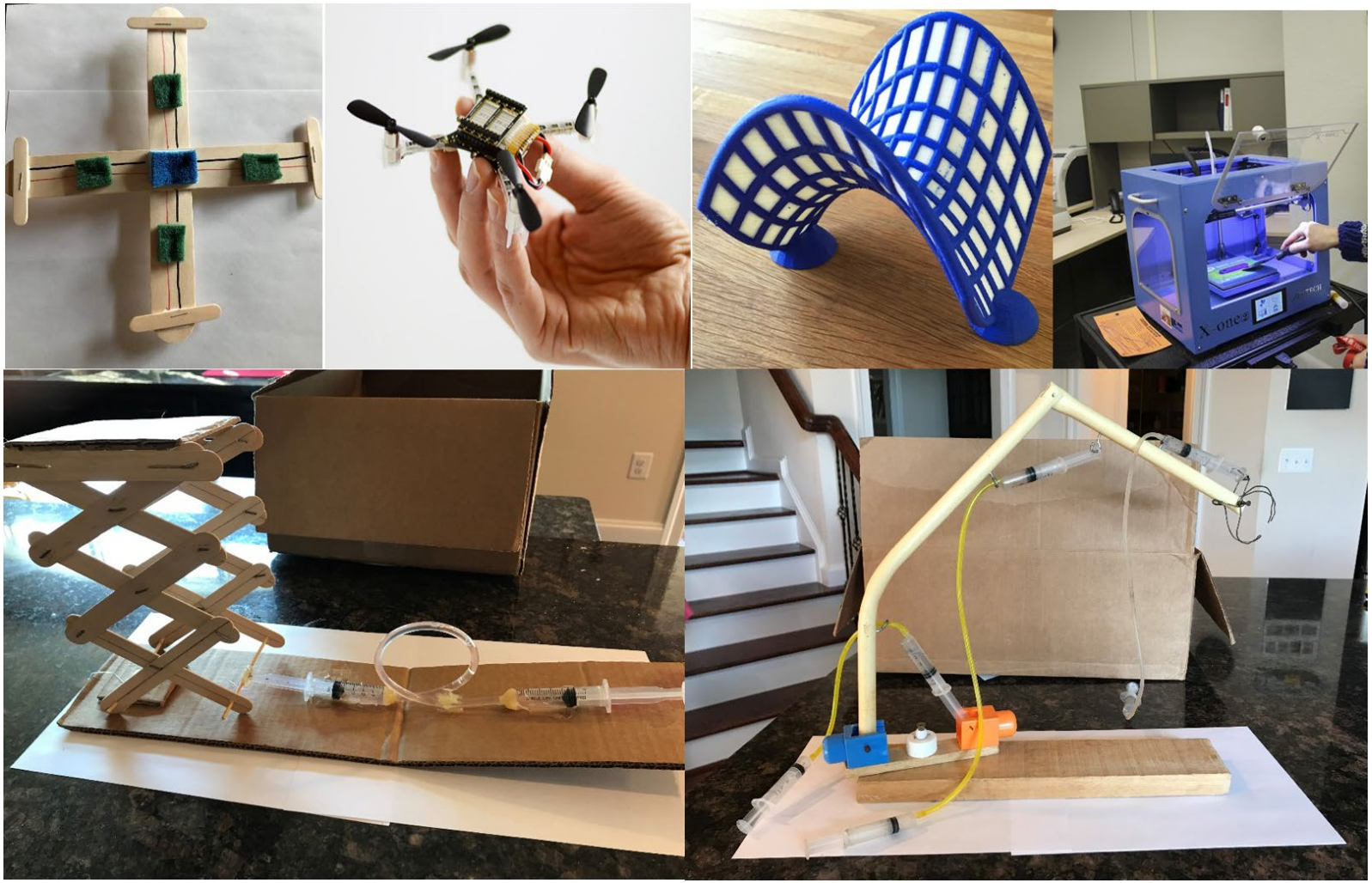
Learning by Doing



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Collaborative Learning

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Active Learning

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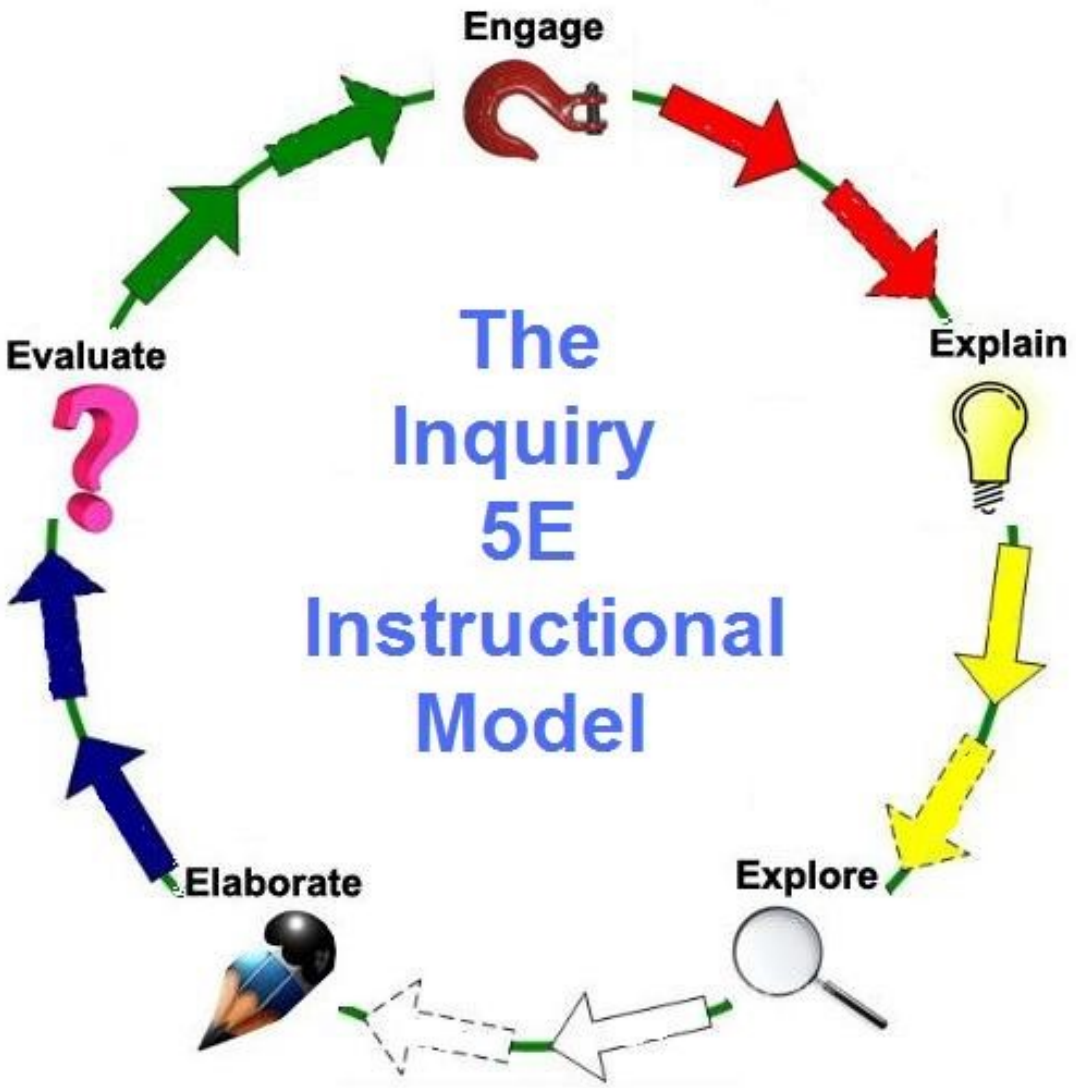
Integrated Teaching



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Performance based Assessment

Avaliação

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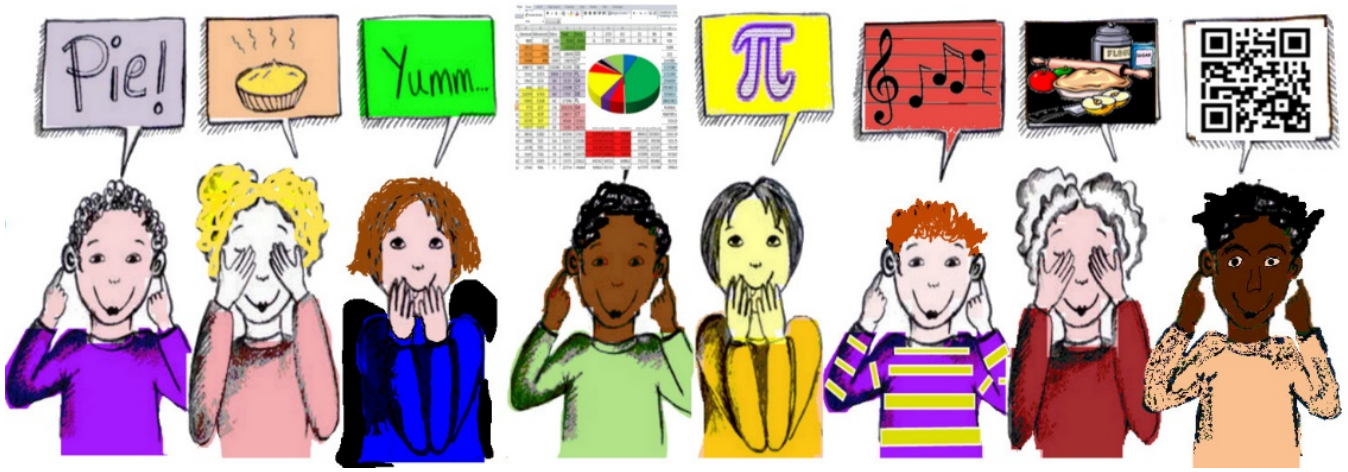
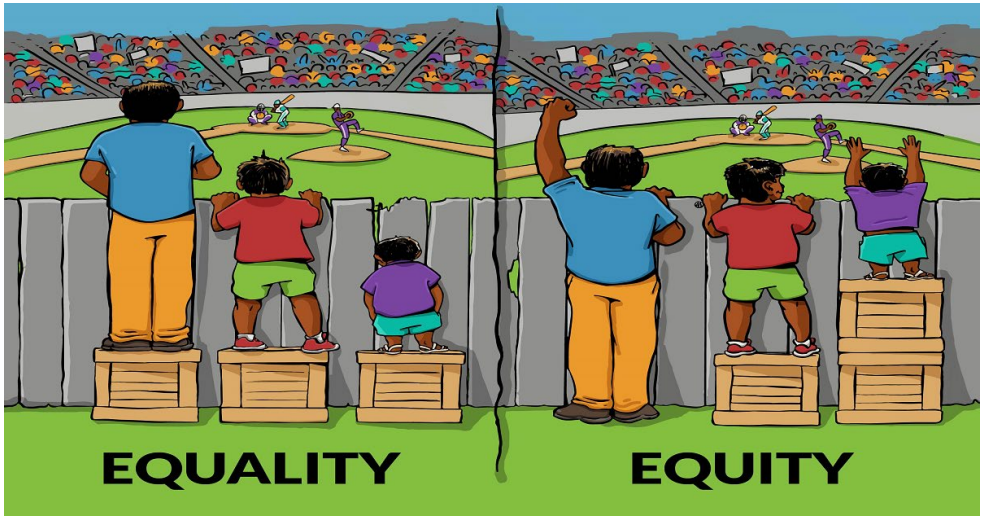
Differentiated Instruction

Aprendizado diferenciado





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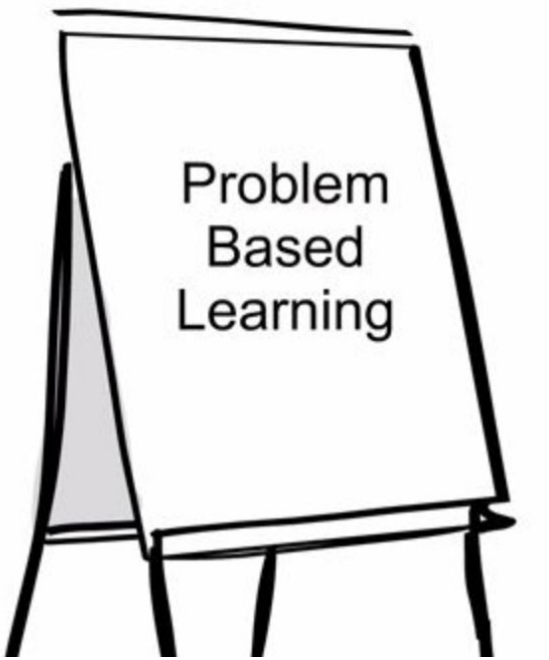
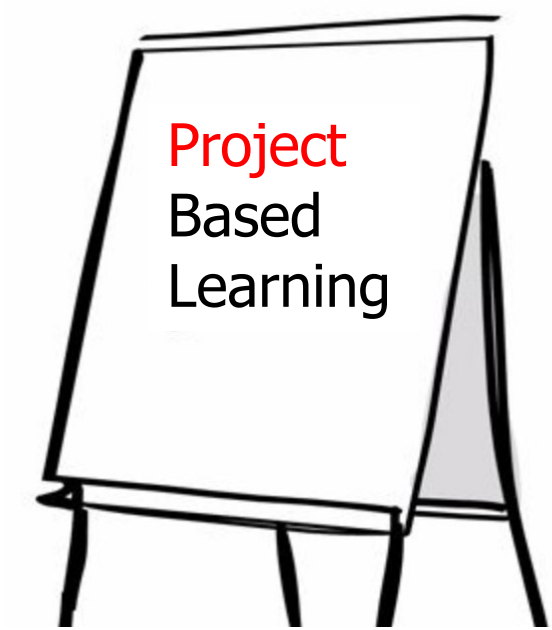
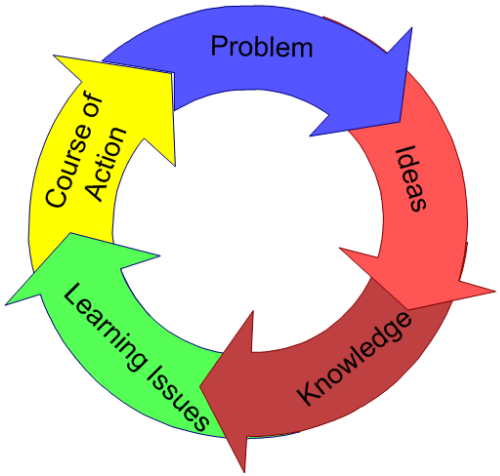
PBL







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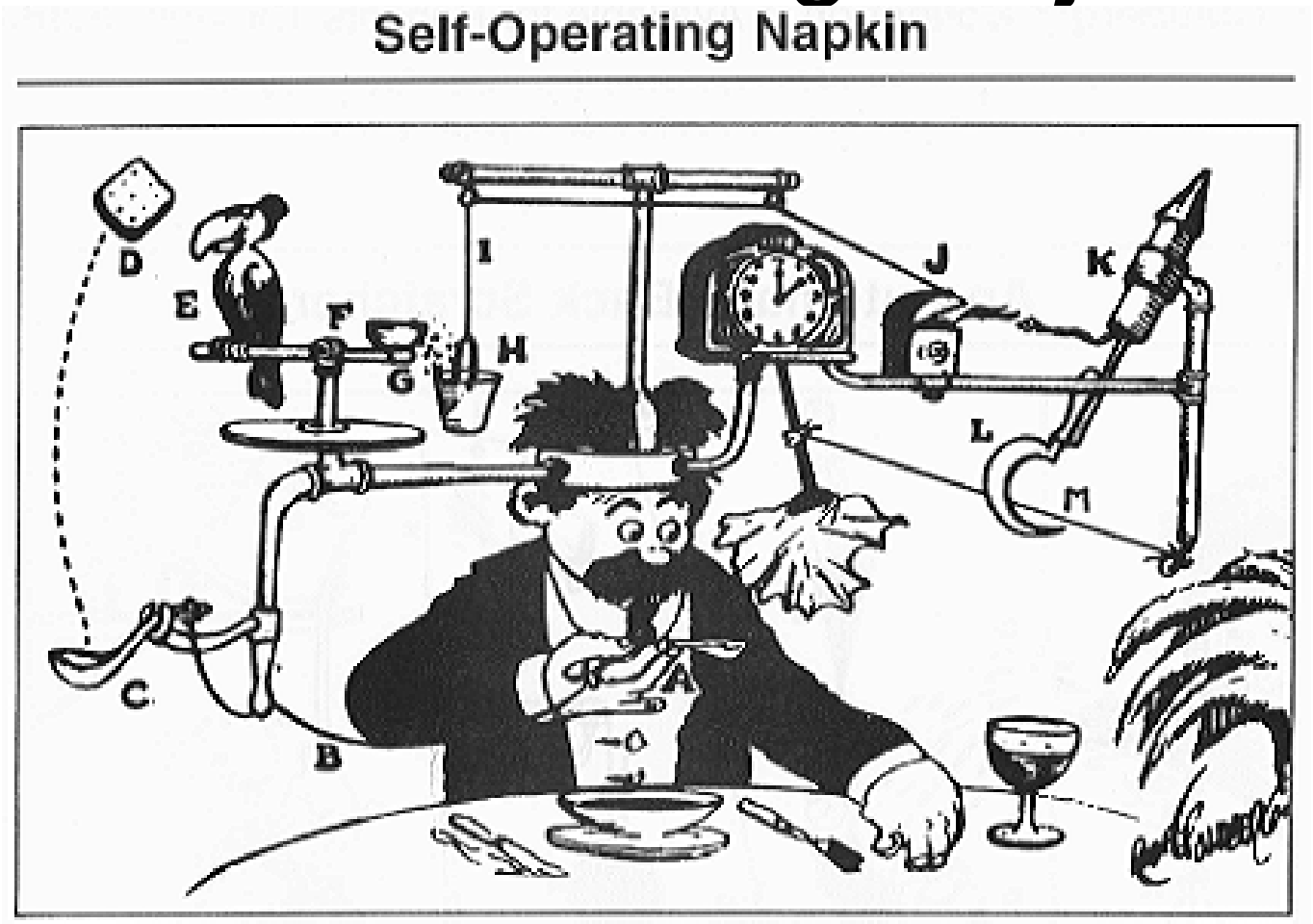
Problem Based Learning
Rube-Goldberg Project



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Project Based Learning
Save the Turtles

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Challenge Based Learning


Make solar energy economical


Provide energy from fusion


Develop carbon sequestration methods


Manage the nitrogen cycle


Provide access to clean water


Restore and improve urban infrastructure


Advance health informatics


Engineer better medicines


Reverse-engineer the brain


Prevent nuclear terror


Secure cyberspace


Enhance virtual reality


Advance personalized learning


Engineer the tools of scientific discovery

GRAND CHALLENGES FOR ENGINEERING

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Challenge Based Learning

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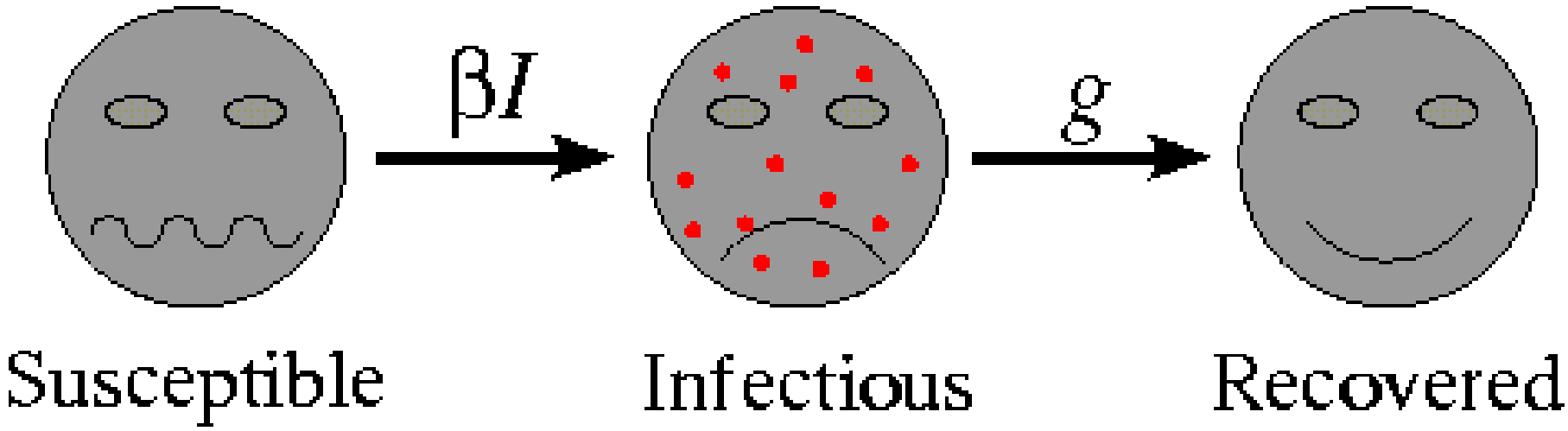
Disease Dynamics Modeling
Identifying the threshold or tipping point
(Kermack and McKendrick, 1927, 1932, 1933)

- Individuals are found in three stages
  - **Susceptible**
  - **Infected**
  - **Recovered**



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Mathematics of Spread of Disease

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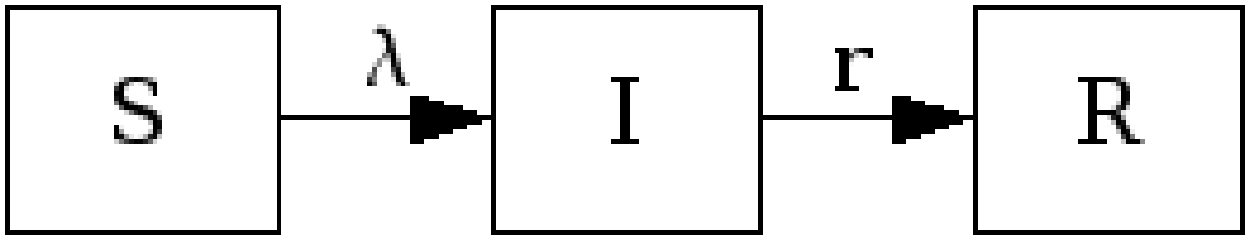
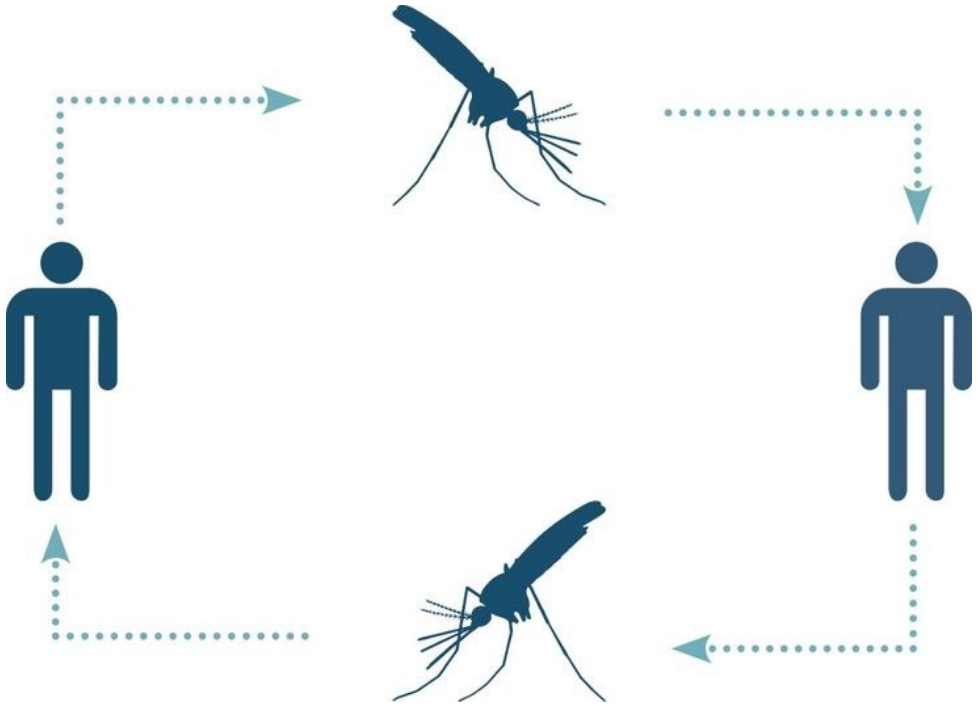
SIR





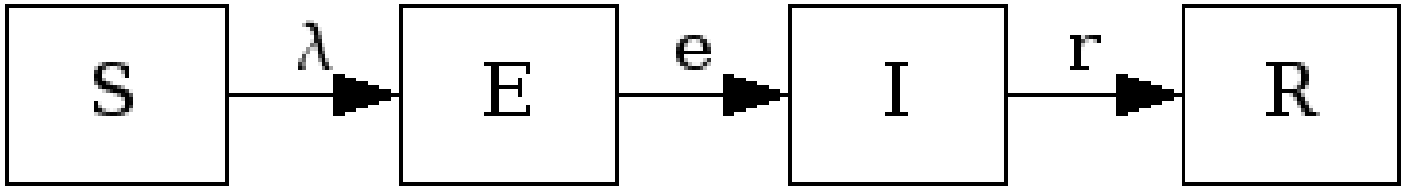
$$\frac{dS}{dt} = -\lambda S I$$

$$\frac{dI}{dt} = \lambda S I - r I$$

$$\frac{dR}{dt} = r I$$

$$S(t) + I(t) + R(t) = N$$

SEIR



Padmanabhan, P., Seshaiyer, P., & Castillo-Chavez, C. (2017). Mathematical modeling, analysis and simulation of the spread of Zika with influence of sexual transmission and preventive measures. *Letters in Biomathematics*, *4*(1), 148-166.

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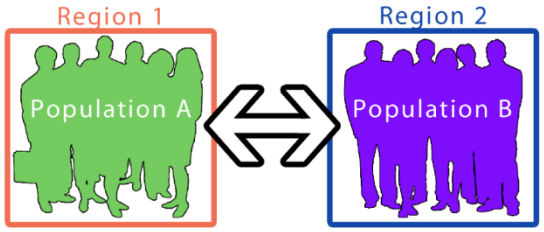
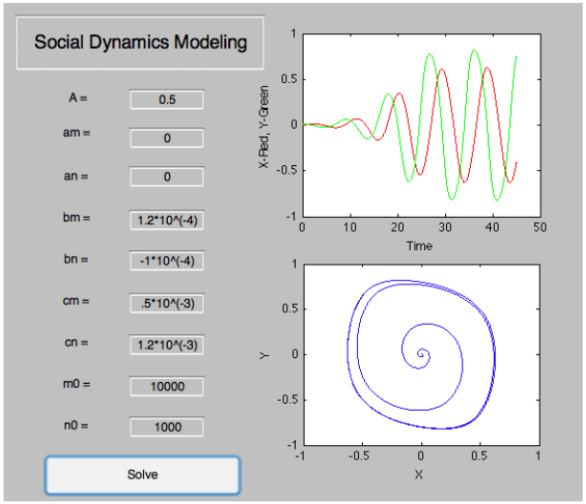
George Mason University

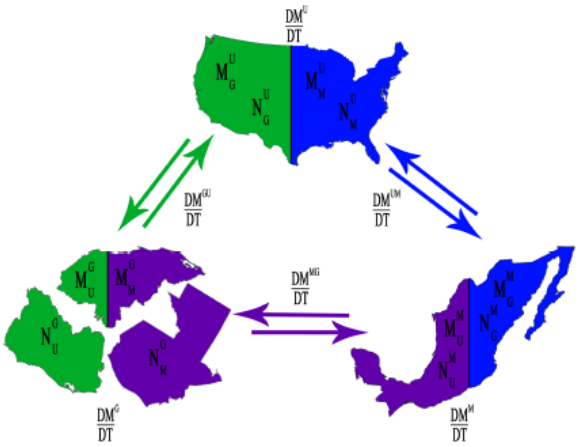
Global Problem Solving

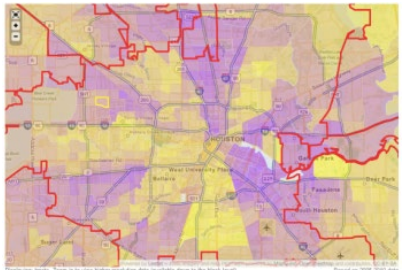
- Location: Houston, TX
- Problem: Social Dynamics

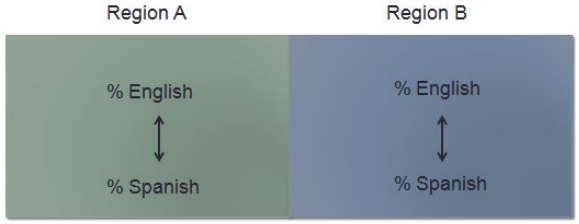
$$\frac{dm_i^{\alpha}(t)}{dt} = \sum_{j=i, j\neq i}^{s} m_j^{\alpha}(t) w_{ij}^{\alpha}(t) - m_i^{\alpha}(t) w_{ji}^{\alpha}(t) + P_i$$

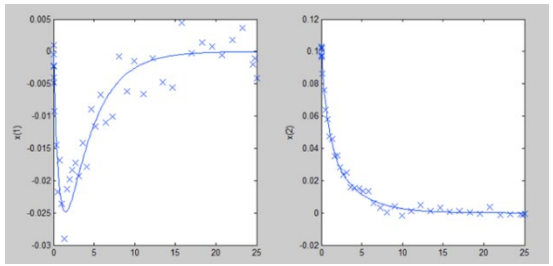












Parameter Estimation

Posters on the Hill

Seshaiyer, P. (2017). Leading Undergraduate Research Projects in Mathematical Modeling. PRIMUS, 27(4-5), 476-493.

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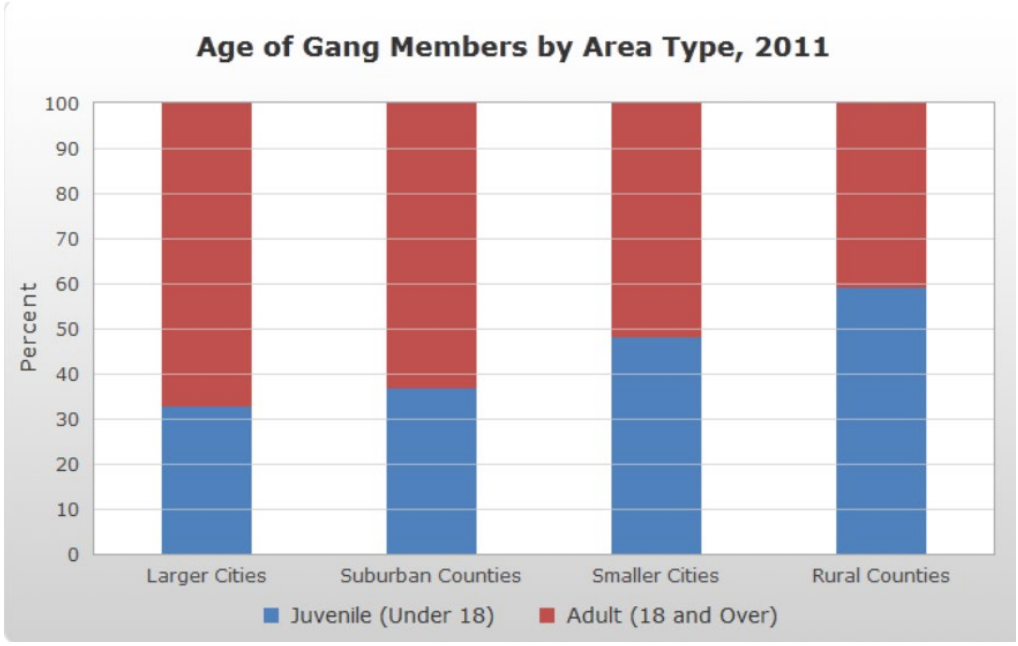
George Mason University

Global Problem Solving

- Location: Houston, TX
- Problem: Gang Recruitment



Rivera-Castro, M., Padmanabhan, P., Caiseda, C., Seshaiyer, P., & Boria-Guanill, C. (2019). Mathematical modelling, analysis and simulation of the spread of gangs in interacting youth and adult populations. Letters in Biomathematics, 1-19.

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George Mason University

Global Problem Solving

- Location: Tanzania
- Problem: Poaching

Padmanabhan, P., Baez, A., Caiseda, C., McLane, K., Ellanki, N., Seshaiyer, P., Kwon, B. & Massawe, E. Design thinking and computational modeling to stop illegal poaching. In 2017 IEEE Integrated STEM Education Conference (ISEC) (pp. 175-181). IEEE.

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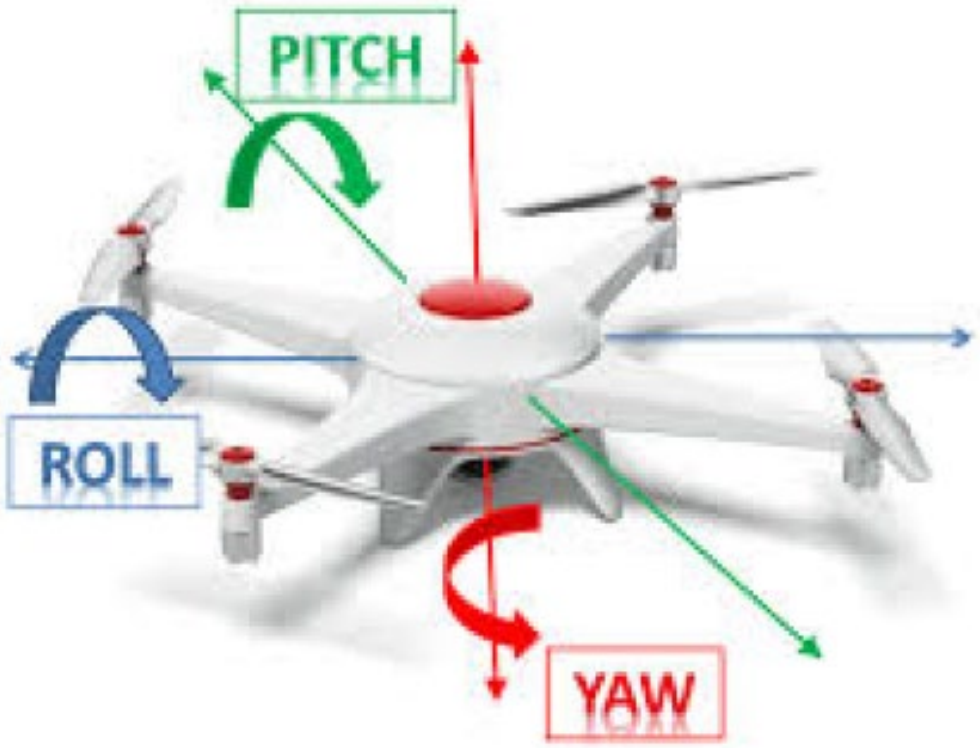
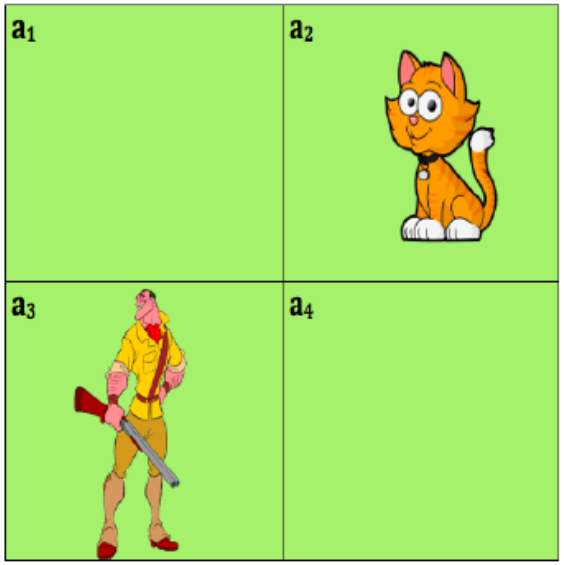
George Mason University

Drones and Mathematics



credit: norunway.com



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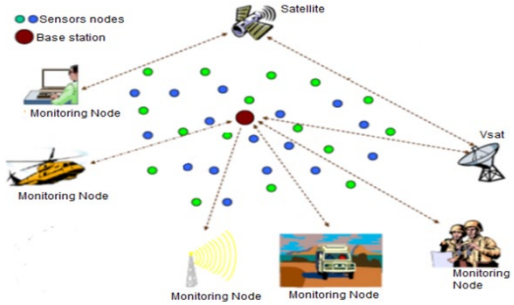
George Mason University

Why is this a rich STEM Problem?

- Dynamics and Mechanics
- Search Algorithms
- Sensors and Electronics
- Control Systems and Feedback
- Communications
- Swarming
- Mapping Algorithms
- Machine Learning



- **Applications**: Anti-poaching, Remote Sensing, Agriculture, Transporting materials, Oil-gas-mineral exploration, Search & Rescue, Surveillance and many more!

Studying Drone Dynamics using Design Thinking and Computational Mathematics

https://sinews.siam.org/Details-Page/applying-design-thinking-to-mathematics-research-2

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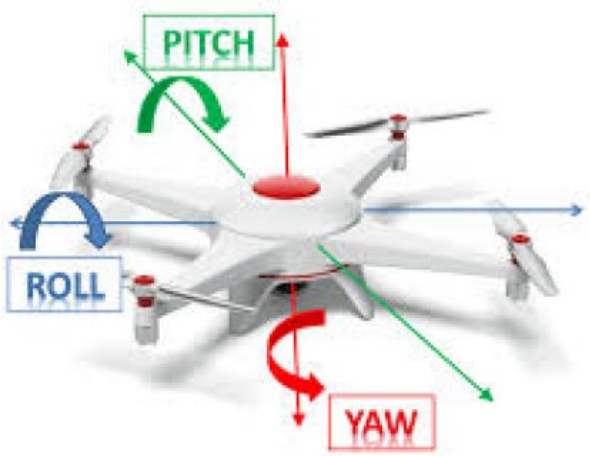
George Mason University

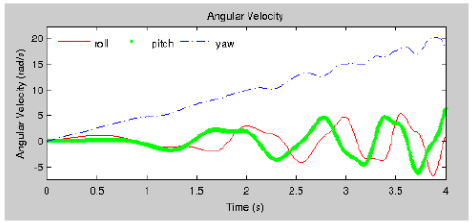
Drones and Mechanics

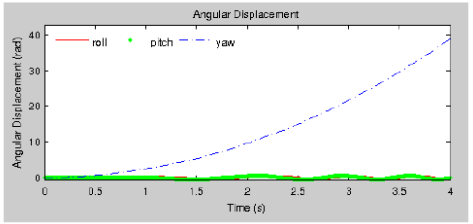


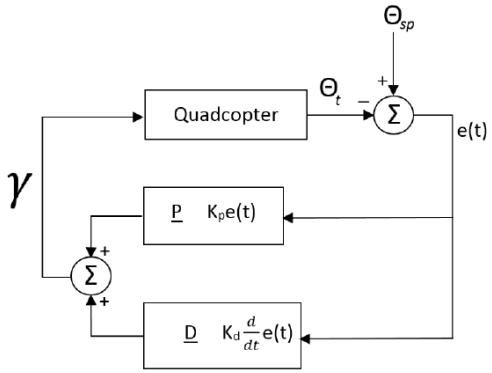
credit: norunway.com

$$\begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix} = \sum \frac{\mathbf{F}}{m} = \frac{1}{m} f_T \mathbf{R} \begin{bmatrix} 0 \\ 0 \\ \sum_{i=1}^{4} \gamma_i^2 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix} + \frac{1}{m} f_D \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix}$$

$$\begin{bmatrix} \dot{\omega}_\phi \\ \dot{\omega}_\theta \\ \dot{\omega}_\psi \end{bmatrix} = \begin{bmatrix} I_{xx} & 0 & 0 \\ 0 & I_{yy} & 0 \\ 0 & 0 & I_{zz} \end{bmatrix}^{-1} \begin{bmatrix} \tau_\phi - (I_{zz} - I_{yy})\omega_\theta\omega_\psi \\ \tau_\theta - (I_{xx} - I_{zz})\omega_\psi\omega_\phi \\ \tau_\psi - (I_{yy} - I_{xx})\omega_\phi\omega_\theta \end{bmatrix}$$







- $e(t) = \Theta_{sp} - \Theta_t$
- $\Theta_{sp} = \begin{bmatrix} 0 \\ 0 \\ \psi_o \end{bmatrix}$
- $K_p, K_d > 0$

$$PD\ Control = K_p e(t) + K_d \frac{d}{dt} e(t) \rightarrow \gamma = [\gamma_1, \gamma_2, \gamma_3, \gamma_4,]$$

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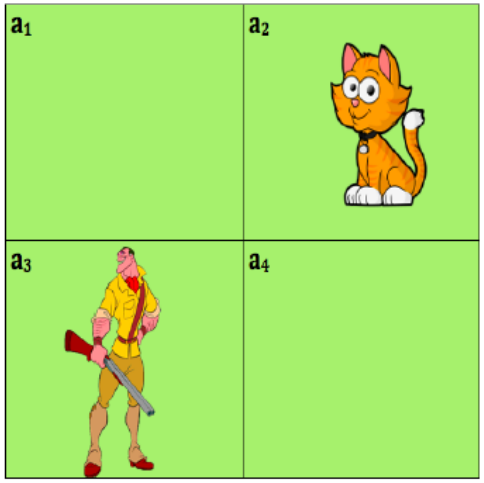
Drones and Target Detection



Target Detection

$$d_{a_i}^t = \begin{cases} 0 & \text{if } x_\tau \neq a_i \text{ at time } t \\ 1 & \text{if } x_\tau = a_i \text{ at time } t \end{cases}$$

Measurement Error

- β = missed detection (missing the poacher)
- α = false alarm (detecting something that's not there; a ranger, a cat, etc)

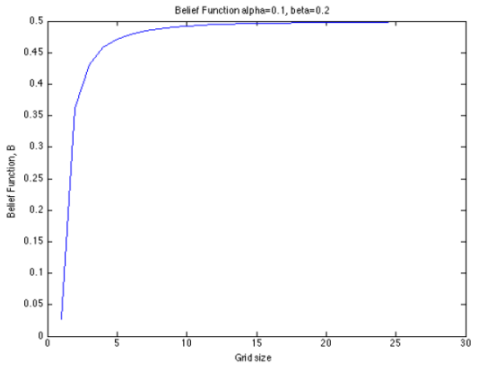
$$Bel(x_\tau) = Pr(x_\tau = a_k | D^t) = \frac{Pr(d_k^t | x_\tau = a_k, D^{t-1}) Pr(x_\tau = a_k | D^{t-1})}{Pr(d_k^t | D^{t-1})}$$

Theorem

For a uniform distribution, the belief function:

$$Pr(x_\tau \in A | D^t = \mathbf{0}) = \frac{t\beta\delta + (1-\alpha)(|A| - t)\delta}{t\beta\delta + (1-\alpha)(|A| - t\delta)}$$

converges to the prior belief, δ.



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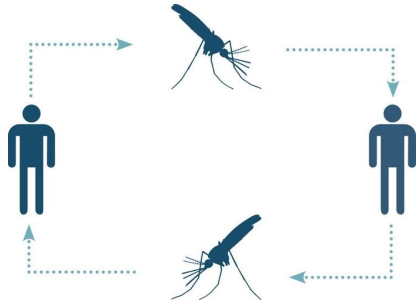
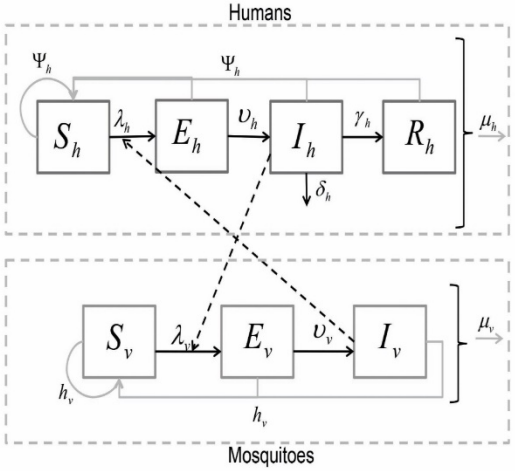
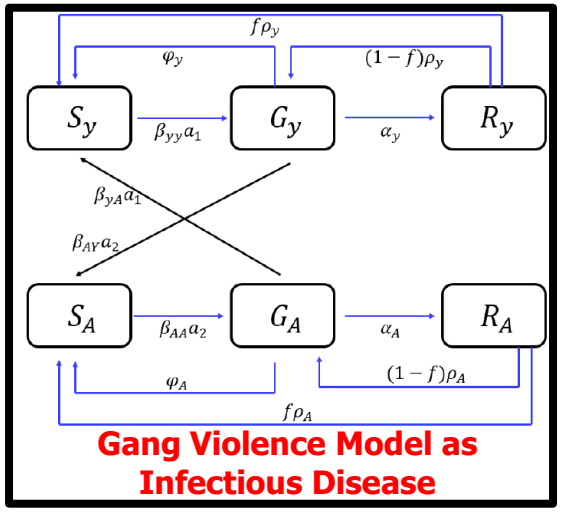
Innovation to Entrepreneurship
Zika-Gangs-Opioids-Wearables



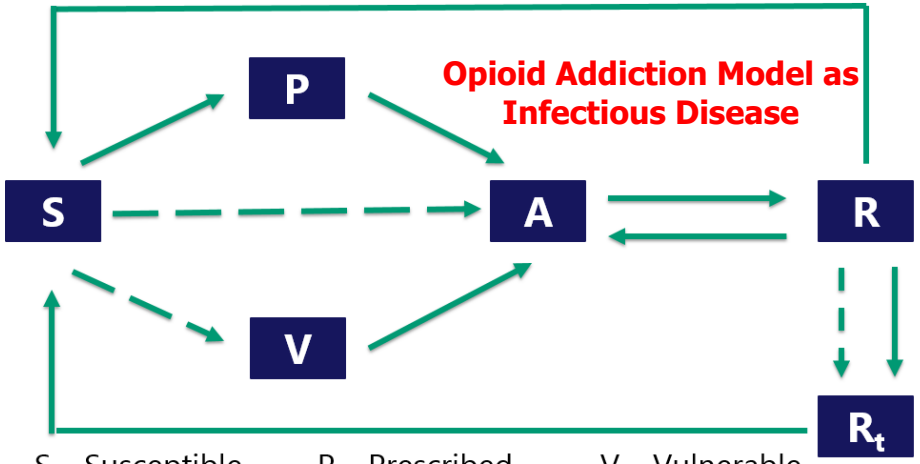
Modeling Infectious Diseases





Gang Violence Model as Infectious Disease

Using Mathematical Modeling, Computer Science, Machine Learning, Mobile App Development to help Opioid Patients



Opioid Addiction Model as Infectious Disease

S – Susceptible
P – Prescribed
V – Vulnerable
A – Addicted
R – Rehabilitation
- - Interaction
Rt – Rehabilitation via Technology
– Change of State

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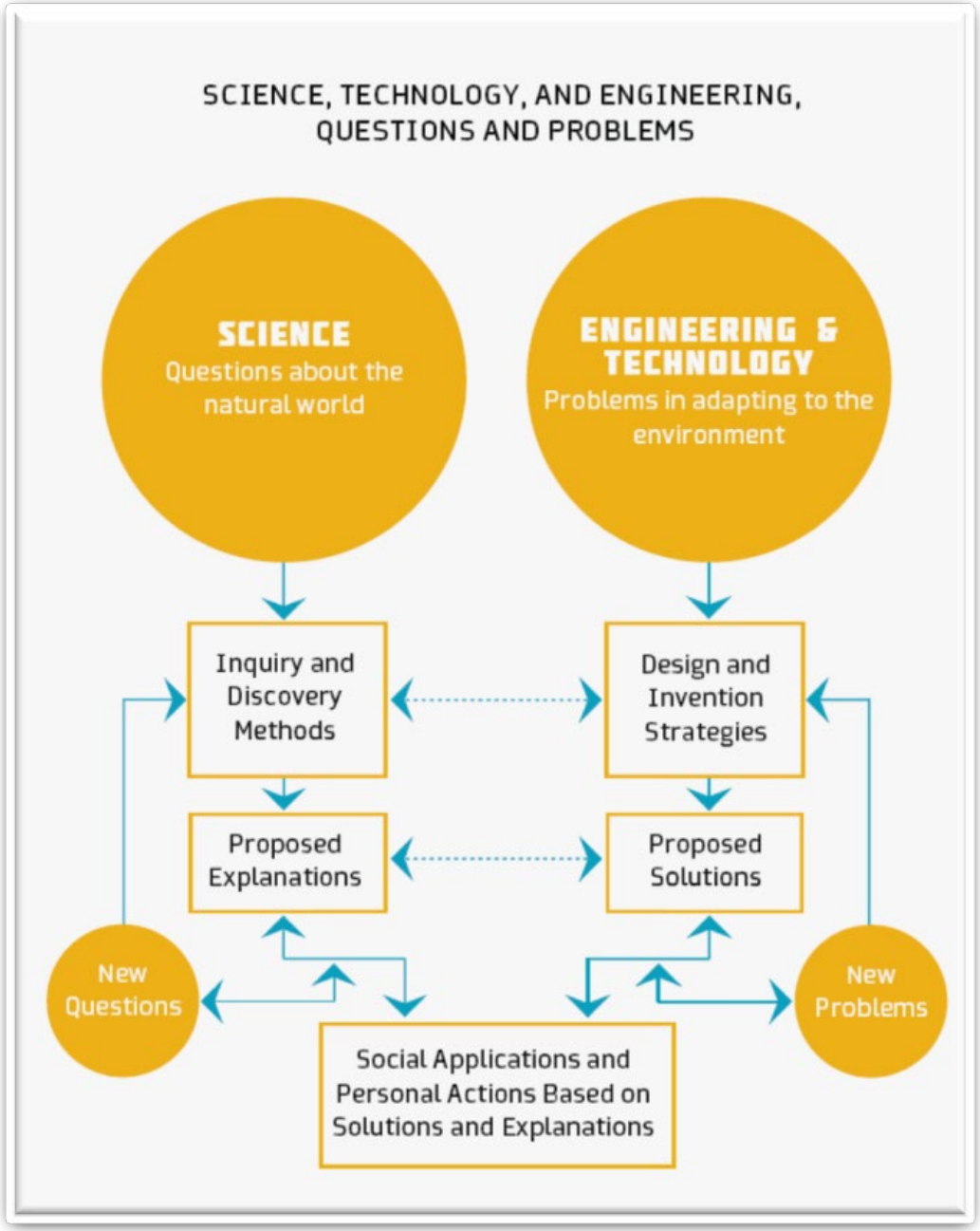

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Multidisciplinary Approach to Engage Diverse Learner in Applied Mathematics Education

- As concluded by the National Research Council: *Undergraduate education will not change in a permanent way through the efforts of "Lone Rangers." Change requires ongoing interaction among communities of people and institutions that will reinforce and drive reform.*

- Research that happens across traditional STEM disciplines and at the edges of traditional disciplines.

- *Here is the problem,*

  find the Mathematics to solve it!

Criminal Investigations and Network Analysis
A DHS CENTER OF EXCELLENCE

Virtual Event

CINA Distinguished Speaker Series

Mathematics for Solving Global Challenges Involving Criminal Activities

Date: Thursday April 30rd, 2020
Time: 12:00-1:30pm
Location: Virtual Event

Featuring:

RSVP and livestream link at cina.gmu.edu/cinaseries

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TEDx

https://www.youtube.com/watch?v=Ybxnfv2O3k4