# Designing Creative Courses with Students in Mind

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UNIVERSITY OF TORONTO

**TODAY**

My background
Why you might consider creative
course design
How to design creative courses
*(Design Stories throughout)*

ON "CREATIVE"

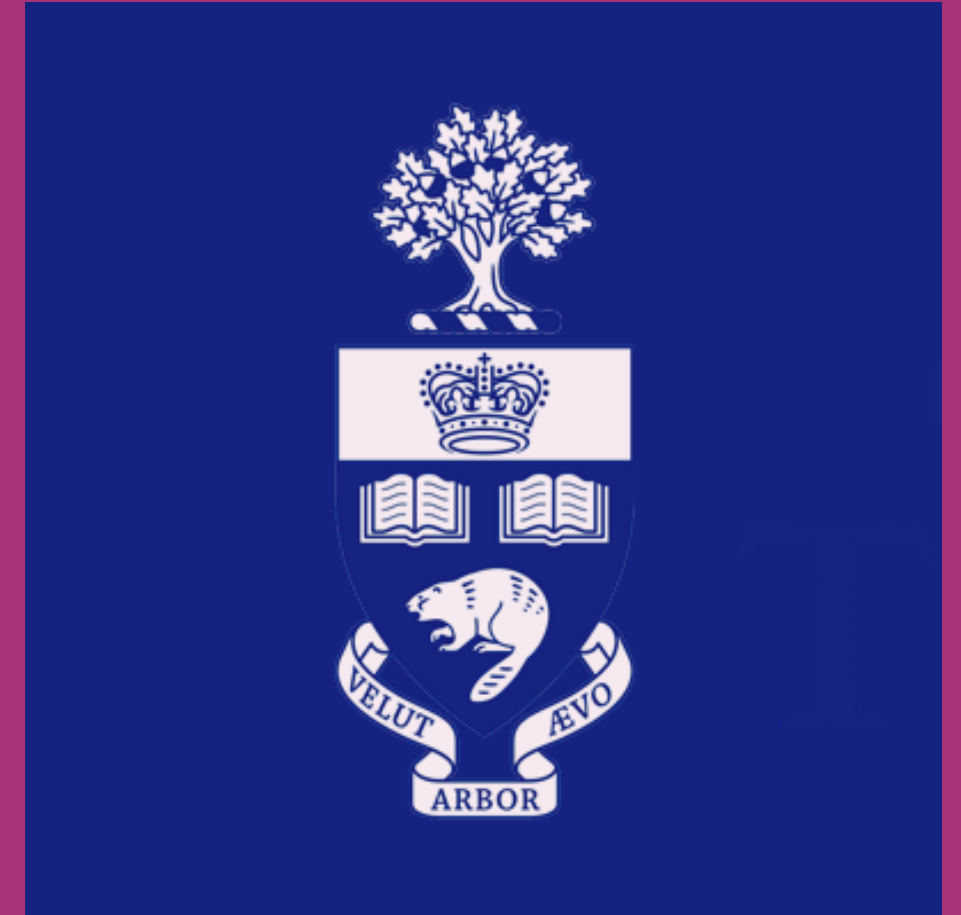You are more creative than you think

Most of my ideas come from others

UNIVERSITY OF MICHIGAN

Reaping benefits of innovation

QUEST UNIVERSITY

"Question Everything"

UNIVERSITY OF TORONTO

Traditional – interested in innovation?
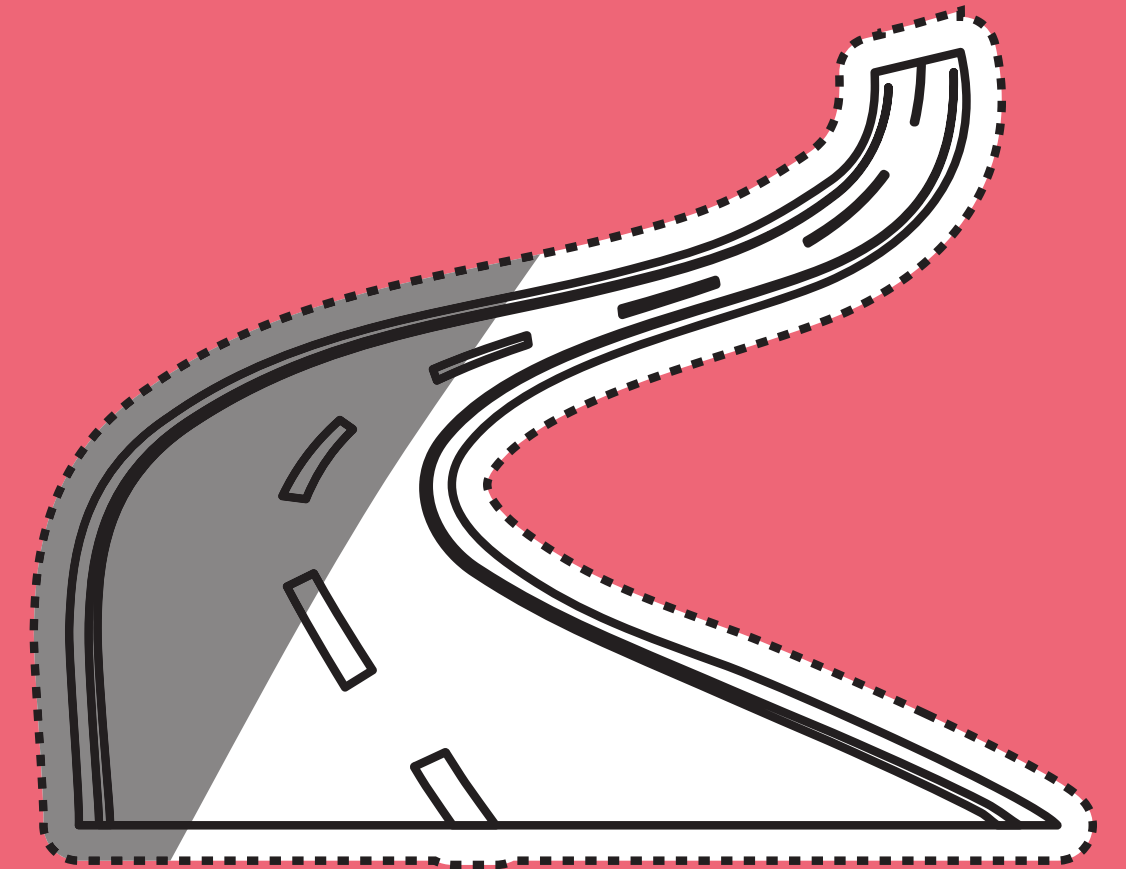
What is Math, Really?

Creativity in Math

Cryptography

Math & Literature

Women's Math

"Education should be an itch, not a scratch."

INTRODUCTION TO ABSTRACT MATH

## Mathematical Masterpieces

CALCULUS FOR BIO MAJORS

## Scientific Modelling and Quantitative Communication

# WHY?
modern citizens

equity & inclusion

it's fun!

# HOW?
inspiration

execution

# 1. THE NATURE OF KNOWLEDGE HAS CHANGED

"By instructing students how to learn, unlearn and relearn, a powerful new dimension can be added to education...Tomorrow's illiterate...will be the man who has not learned how to learn."

# TOO MUCH INFORMATION

lifelong learners

# NEW UNDERSTANDINGS REPLACING OLD ONES

learning skills

# PROBLEM SOLVING VITAL

active problem solving

practice

# INFORMATION IS ACCESSIBLE

information management

(Weimer,Learner-Centered Teaching)

**TOO MUCH INFORMATION**

lifelong learners

**NEW UNDERSTANDINGS REPLACING OLD ONES**

learning skills

**21st c. learners**

**PROBLEM SOLVING VITAL**

active problem solving

practice

**INFORMATION IS ACCESSIBLE**

information management

(Weimer, Learner-Centered Teaching)

# DESIGN STORY: CALCULUS FOR SCIENCE

- 1st year students can't understand math in a science paper
- without grading time, you cannot assign a meaningful project

# DESIGN STORY: CALCULUS FOR SCIENCE

1st year students can't understand this

servoir computing except that neurons con- ... gular-spiking (RS) and bursting modes (Fig. ... isolates spikes (Fig. 1b) whereas they are ... strongly bursty in the bursting mode (Fig. 1c). Neurons in the reservoir project to two readout

71 neurons to describe the two-dimensional coordinates $(x_1, x_2)$ of Lévy flight, and the outputs of

72 these neurons are fed back to all neurons in the reservoir. We describe neurons in the reservoir

73 with the Izhikevich model, which is able to mimic the temporal discharging patterns of various

74 neurons [47]:

$$
\begin{aligned}
\frac{dv_i}{dt} &= 0.04v_i^2 + 5u_i + 140 - u_i + I_i, \\
\frac{du_i}{dt} &= a(bv_i - u_i),
\end{aligned}
\tag{1}
$$

75 where $a = 0.02$ and $b = 0.2$, and $i$ is a neuron index. We set as $c = -65$ mV and $d = 8$ in the

76 RS mode and $c = -50$ mV and $d = 2$ in the bursting mode. The values of $v_i$ and $u_i$ are reset to $c$

77 and $u_i + d$ when $v_i$ reaches the threshold of 30 mV. We use this model for simplicity of numerical

78 simulations although the Izhikevich model does not take refractory periods into account and may

79 exhibit unrealistically high frequency bursting.
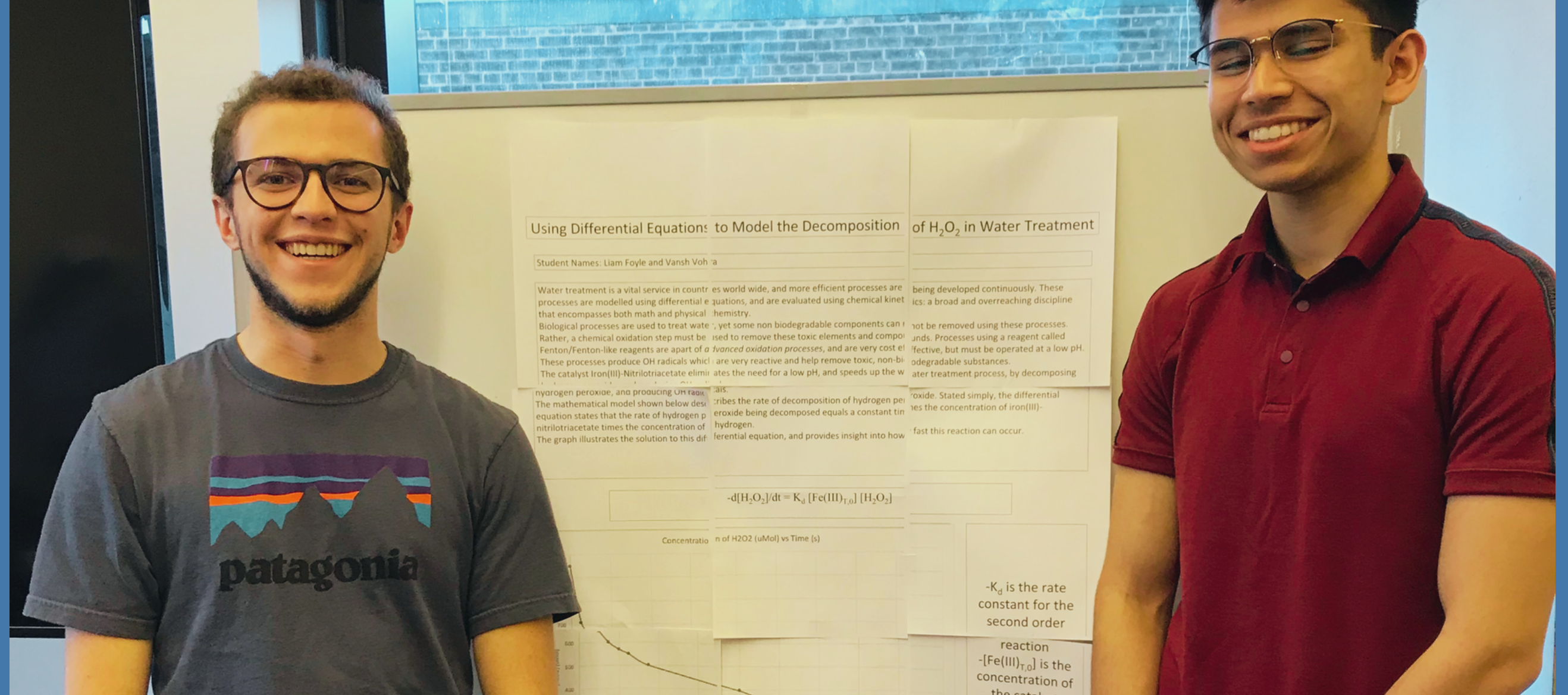
# DESIGN STORY: CALCULUS FOR SCIENCE

What *can* first year students understand?

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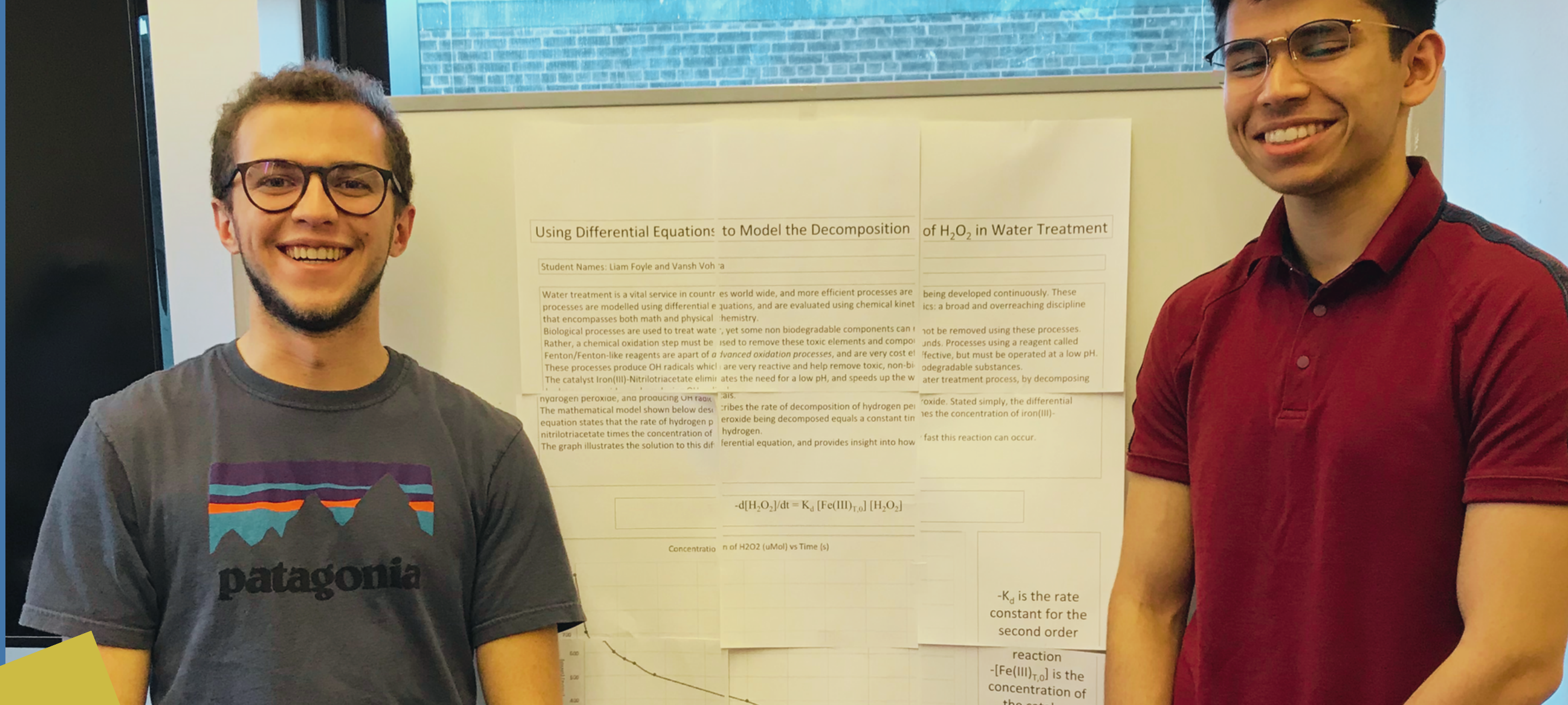
79 exhibit unrealistically high frequency bursting.

# DESIGN STORY: CALCULUS FOR SCIENCE

poster project: base project in tutorials, use peer feedback, expect isntructors to grade more… make it

The poster text reads:

**Using Differential Equations to Model the Decomposition of $H_2O_2$ in Water Treatment**

Student Names: Liam Foyle and Vansh Vohra

Water treatment is a vital service in countries world wide, and more efficient processes are being developed continuously. These processes are modelled using differential equations, and are evaluated using chemical kinetics: a broad and overreaching discipline that encompasses both math and physical chemistry.
Biological processes are used to treat water, yet some non biodegradable components can not be removed using these processes. Rather, a chemical oxidation step must be used to remove these toxic elements and compounds. Processes using a reagent called Fenton/Fenton-like reagents are apart of advanced oxidation processes, and are very cost effective, but must be operated at a low pH. These processes produce OH radicals which are very reactive and help remove toxic, non-biodegradable substances. The catalyst Iron(III)-Nitrilotriacetate eliminates the need for a low pH, and speeds up the water treatment process, by decomposing hydrogen peroxide, and producing OH radicals.

The mathematical model shown below describes the rate of decomposition of hydrogen peroxide. Stated simply, the differential equation states that the rate of hydrogen peroxide being decomposed equals a constant times the concentration of iron(III)-nitrilotriacetate times the concentration of hydrogen. The graph illustrates the solution to this differential equation, and provides insight into how fast this reaction can occur.

$$-d[H_2O_2]/dt = K_d \, [Fe(III)_{T,0}] \, [H_2O_2]$$

Concentration of H2O2 (uMol) vs Time (s)

$-K_d$ is the rate constant for the second order reaction
$-[Fe(III)_{T,0}]$ is the concentration of the catalyst

# DESIGN STORY: CALCULUS FOR SCIENCE

poster project: base project in tutorials, use peer feedback, expect isntructors to grade more… make it

WHY DESIGN CREATIVE COURSES?
## 2. ATTENTION TO EQUITY, DIVERSITY, AND INCLUSION

Equity

last ___ course ever???

last ___ course ever???

EDI Connection:
1st year of university key point for retention of women in STEM

last ___ course ever???

last ____ course ever???

last ___ course ever???

last ___ course ever???

last ___ course ever???

last ___ course ever???

EDI Connection:
our students will become leaders
in their own communities

# MATH AS A HUMAN ACTIVITY

**Testimonios** Stories of Latinx & Hispanic Mathematicians

all about math
community &
math culture

**DESIGN STORY: WHAT IS MATH, REALLY?**

Q: Why does the Fields medal have an age limit? What are the consequences?

"math as a young man's game"

what we value as (math) society

women's participation in math

role of prizes / awards in math (vs other disciplines?)

"genius" in math

pure vs applied math

professional societies

**DESIGN STORY: WHAT IS MATH, REALLY?**

Project: Discuss an
issue in contemporary
mathematics.

"Anyone can be a
mathematician!"

—

DESIGN STORY: WHAT IS MATH,
REALLY?

Students' own ideas can be so much better than what we could ever dream *for them*.

analysis

calculus

algebra

analysis

calculus

algebra

EDI Connection:
women & minorities more
likely to leave

WHY DESIGN CREATIVE COURSES?
# 3. CAREER SATISFACTION

"I learn like it's my job...
because it is."

"The work of the professor becomes consequential only as it is understood by others. Yet, today, teaching is often viewed as a routine function, tacked on, something almost anyone can do. **When defined as scholarship, however, teaching both educates and entices future scholars.** Indeed, as Aristotle said, 'Teaching is the highest form of understanding.' "

ERNEST BOYER, SCHOLARSHIP RECONSIDERED

# *The Creativity Contract*

## UTOPIA IN OUR JOBS?

"The creativity contract idea may appear utopian, but it is attainable, we believe."–Boyer

above all else, on the and universities that gths and sustain their Henry David Thoreau commenting on his decision to leave the solitary, reflective life at Walden Pond. "I left the woods," he wrote, "for as good a reason as I went there.., it seemed to me that I had several more lives to lead, and could not spare any more time for that one. It is remarkable how easily and insensibly we fall into a particular route, and make a beaten track for ourselves."1

It flies in the face of all experience to expect a professor to engage

WHY?

THE NATURE OF KNOWLEDGE HAS CHANGED
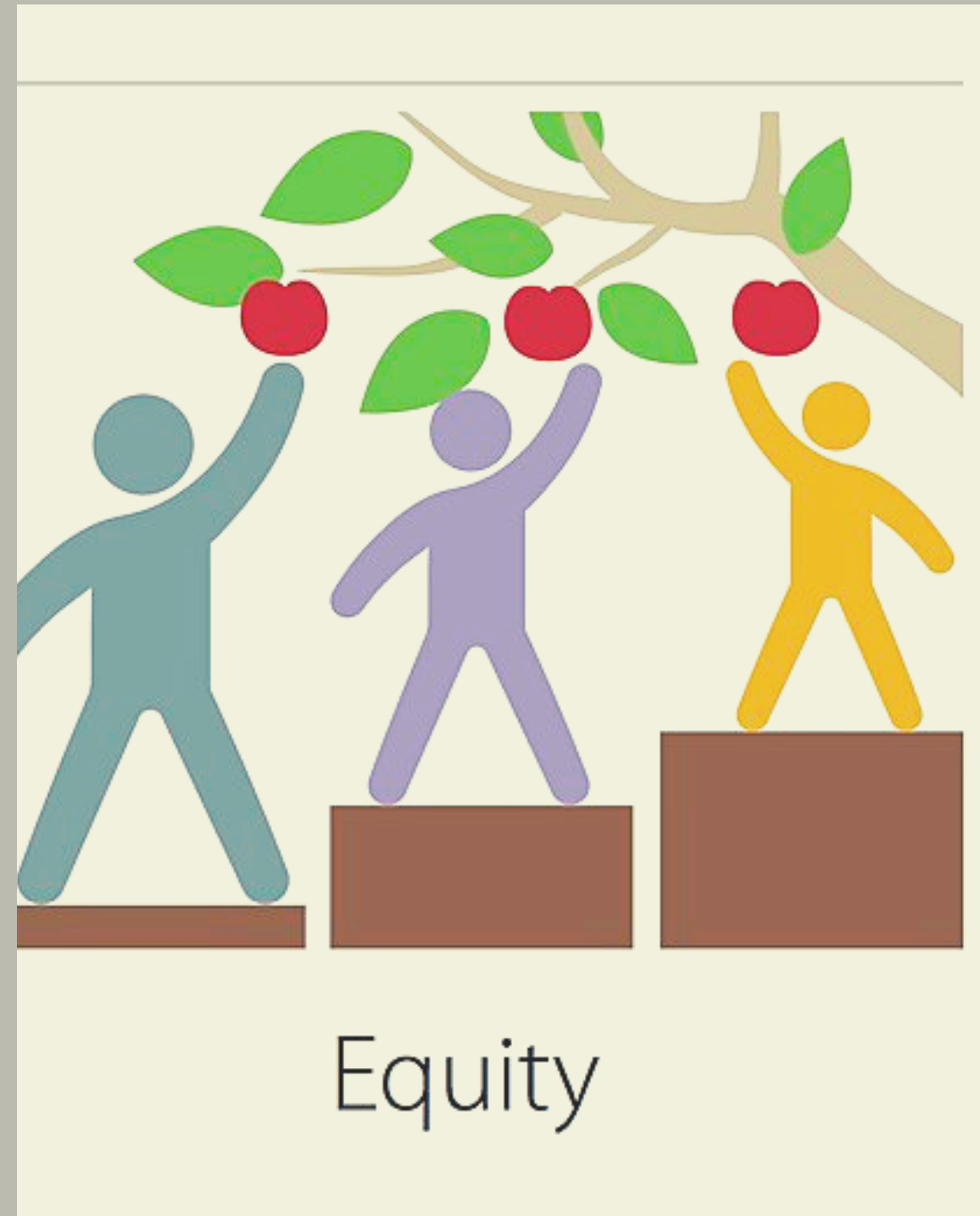
ATTENTION TO DIVERSITY, EQUITY, AND INCLUSION

YOUR OWN CAREER SATISFACTION

Equity

# HOW?

## INSPIRATION & EXECUTION

# MINDSET
# COMMUNITY
# RESOURCES

# HELLO, I'M

*a scholar*

DESIGN STORY:
MATHEMATICAL MASTERPIECES
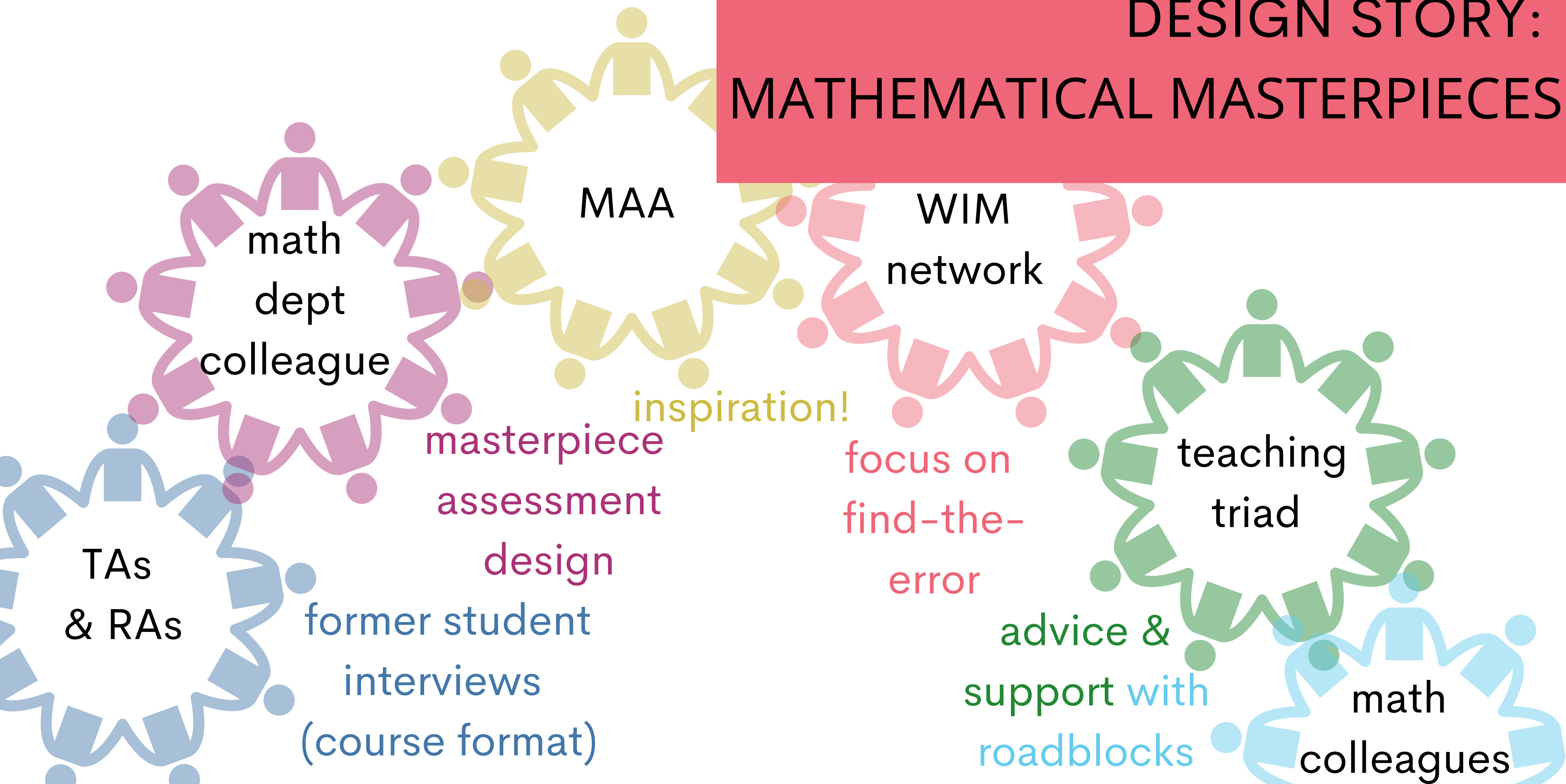
math dept colleague

MAA

WIM network

teaching triad

TAs & RAs

masterpiece assessment design

inspiration!

focus on find-the-error

former student interviews (course format)

advice & support with roadblocks

math colleagues

communities

Centres for Teaching

Profess. Societies

networks

Twitter/ online
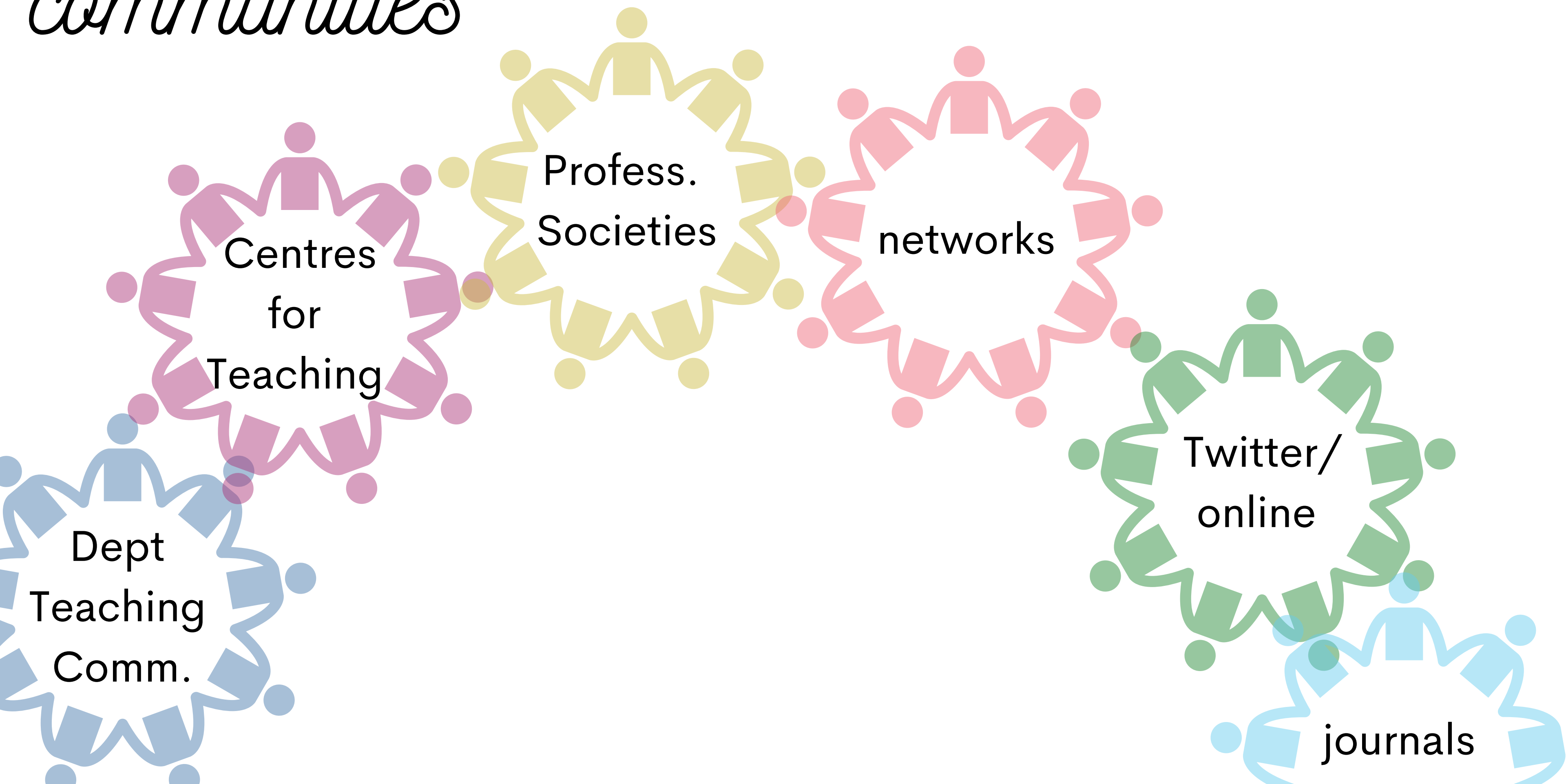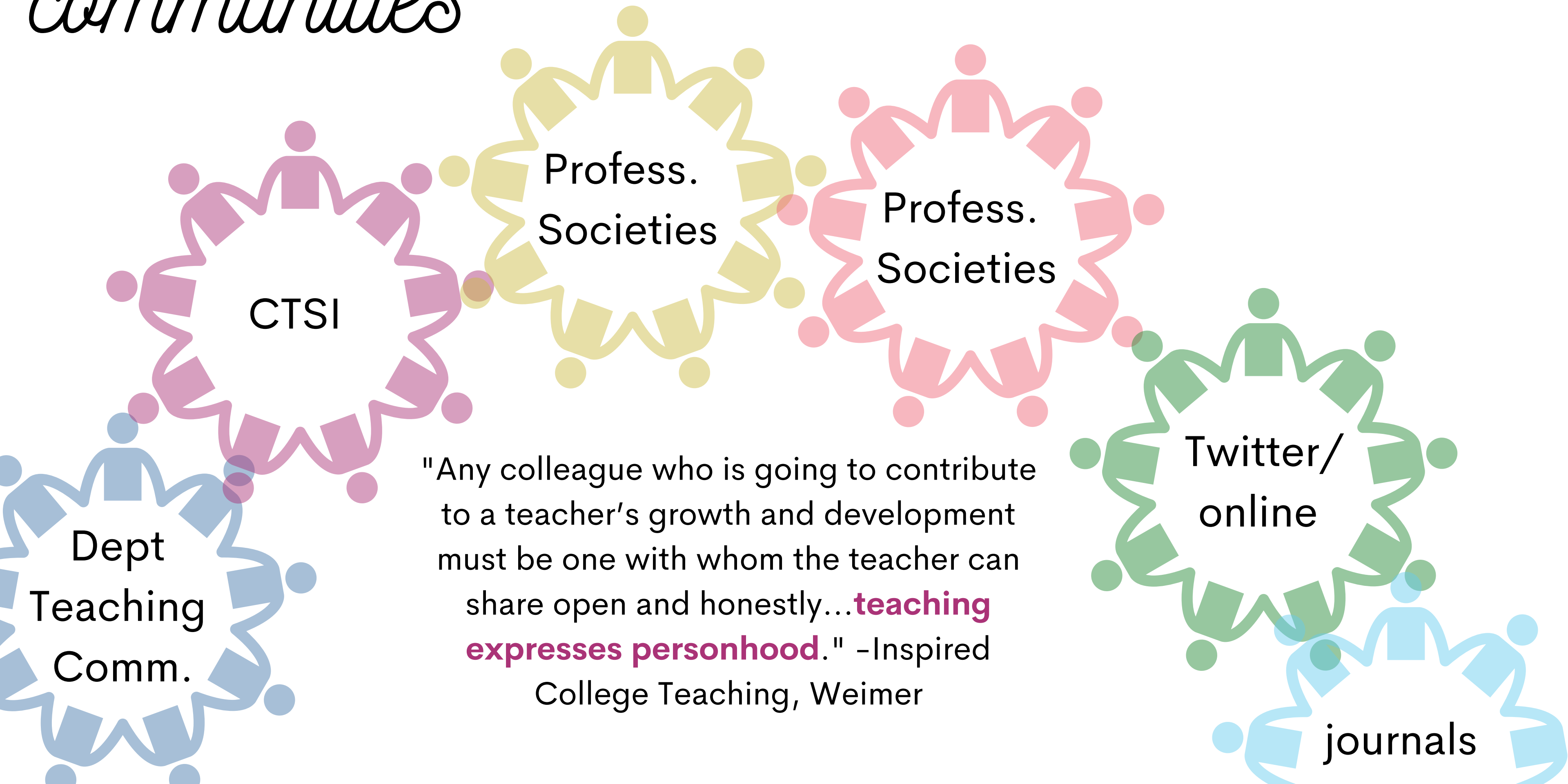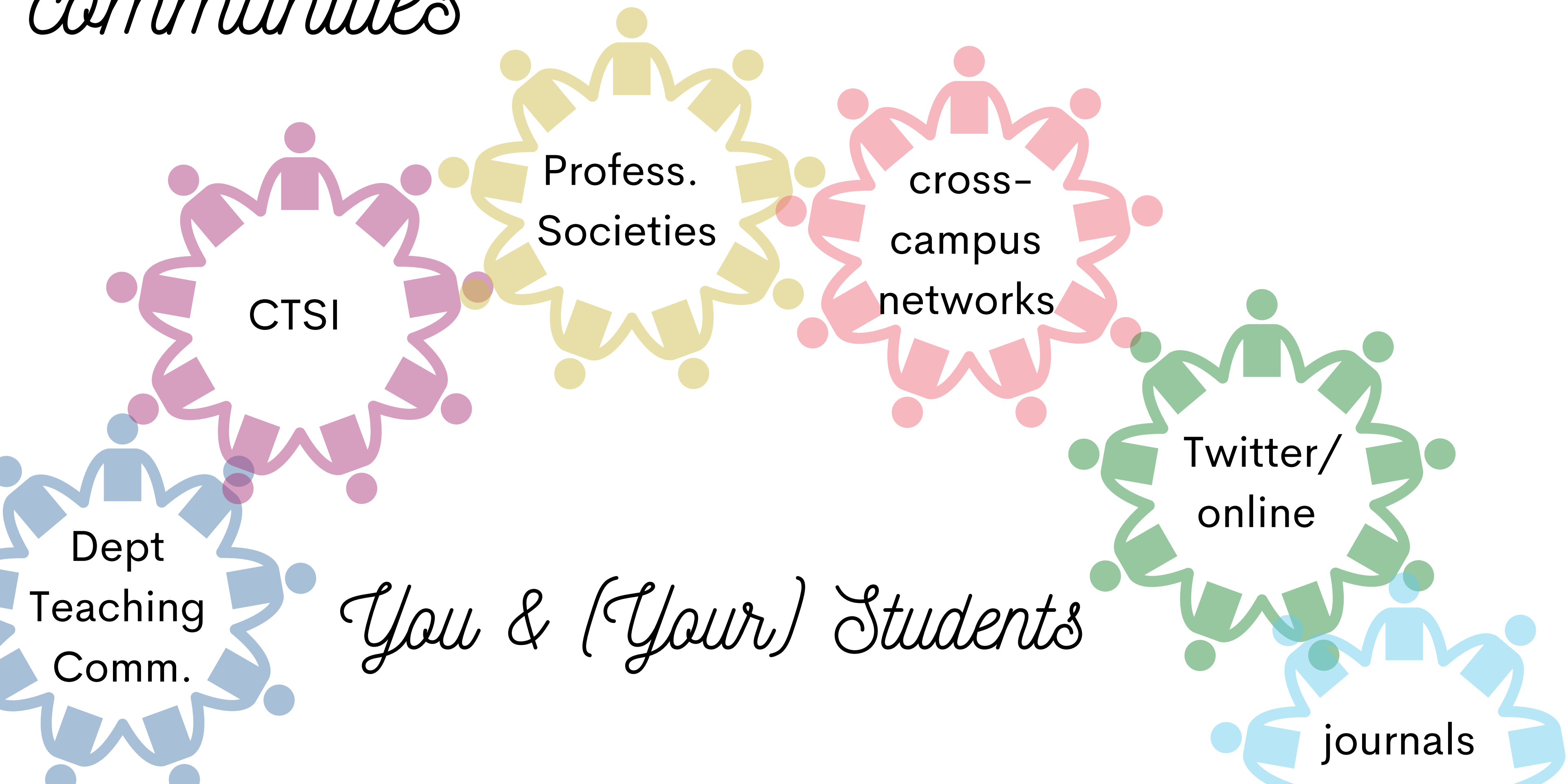
Dept Teaching Comm.

journals

# communities

## CTSI

## Profess. Societies

## Profess. Societies

## Dept Teaching Comm.

## Twitter/ online

## journals

"Any colleague who is going to contribute to a teacher's growth and development must be one with whom the teacher can share open and honestly…**teaching expresses personhood**." –Inspired College Teaching, Weimer

communities

Profess.
Societies

cross-
campus
networks

CTSI

Dept
Teaching
Comm.

You & (Your) Students

Twitter/
online

journals

# DIFFERENT VIEWS ON YOUR OWN DISCIPLINE
including what makes you uncomfortable

# CROSS-DISCIPLINARY
what conversations are happening between disciplines?

**resource curation for creative course design**

The
# Slow
Professor

*Challenging the Culture of Speed in the Academy*

Maggie Berg and Barbara K. Seeber

With a New Foreword by Stefan Collini
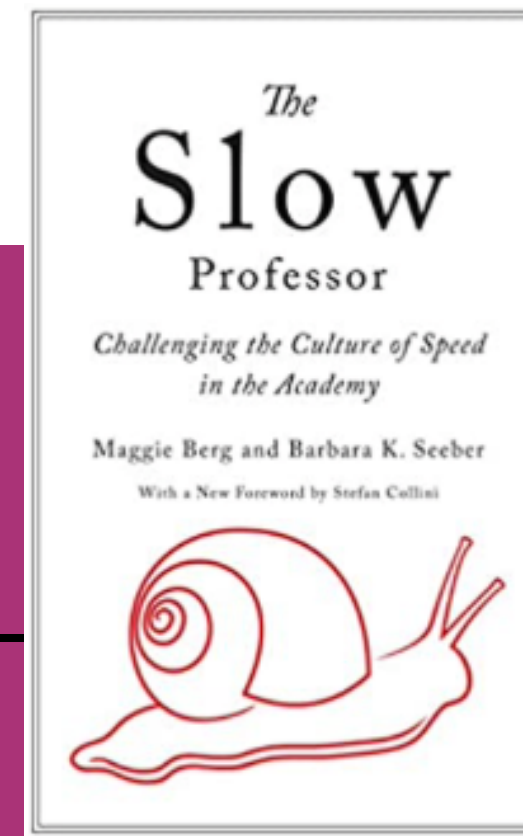
# WITHIN OTHER DISCIPLINES
what are other disciplines talking about?

# ENJOY!
remember a scholarly, slow professor mindset

# EXECUTING CREATIVE

# COURSES

# EXECUTING CREATIVE COURSES

organize around big ideas

do what you believe

be flexible

follow best practices

organize around big ideas

"**Experts** first seek to develop an understanding of problems, and this often involves **thinking in terms of core concepts or big ideas**.  Novices' knowledge is much less likely to be organized around big ideas; novices are more likely to approach problems by searching for correct formulas and put answers that fit their everyday intuitions."

HOW PEOPLE LEARN BY BRANSFORD, BROWN, AND COCKING, 2000
QUOTED IN UNDERSTANDING BY DESIGN

# Coverage?

cover = something on the surface to travel over concealment
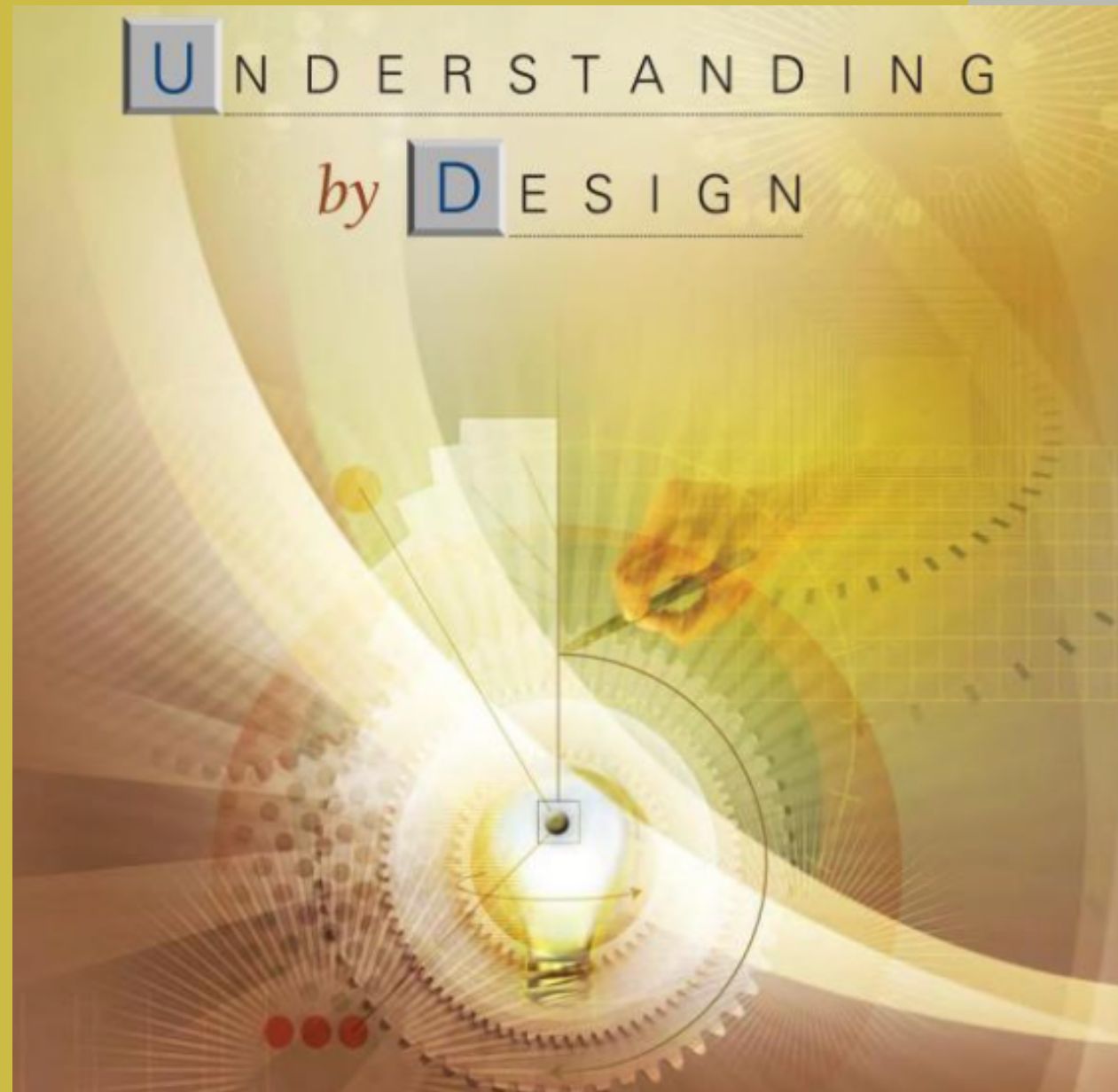
**"Un-coverage"**

(Wiggins, McTighe)

UNDERSTANDING by DESIGN

CECILIA KRIEGER

*One million Hows, two million Wheres,*
*And an infinity of Whys!*

...sity of Vienna,
...oland in 1920.
...d Physics the

DESIGN STORY:WOMEN'S MATH

There seem to be more questions than answers about women in math...

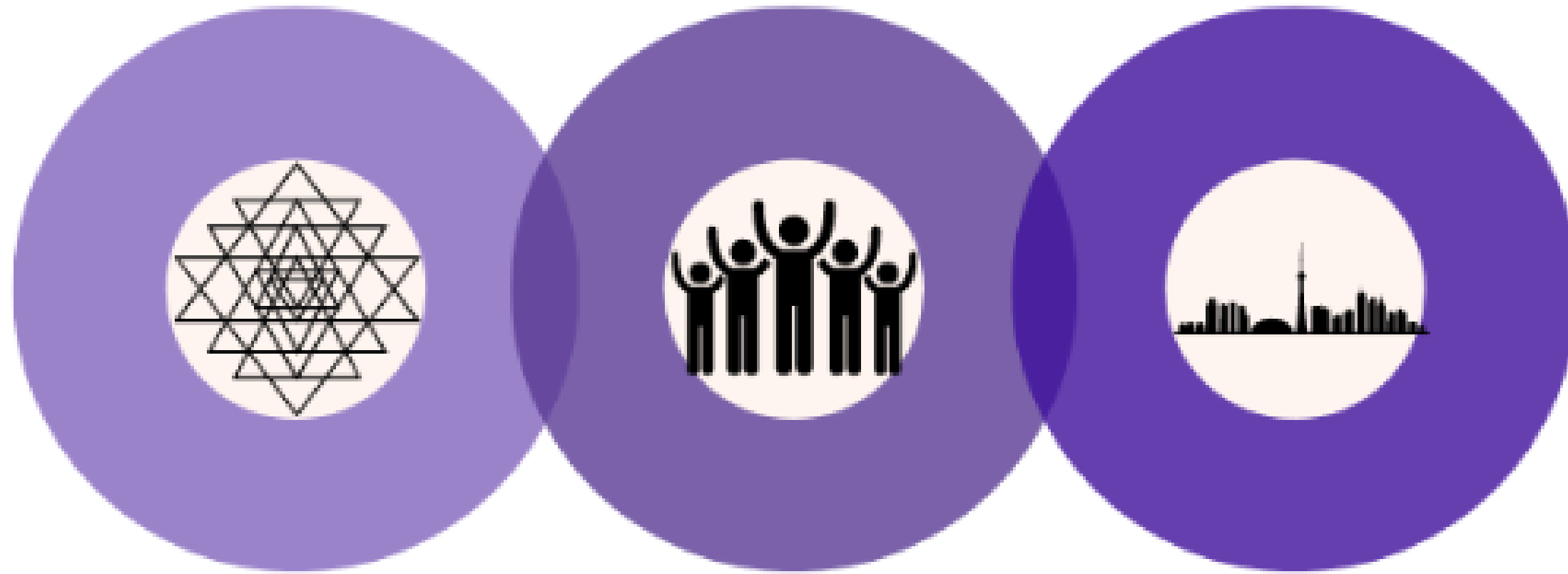We have an illustrious history of women in math, but know little about them...

Our own Department is an interesting case study...

Women are very under-represented now at all levels in the Department...

DESIGN STORY:WOMEN'S MATH

Women's Mathematical Contributions

Societal Environment

Women in Math at UofT

DESIGN STORY:WOMEN'S MATH

do what you believe

DESIGN STORY: MATHEMATICAL CREATIVITY

How do I get students to *experience* mathematical creativity?

...follow any path, go with your interests, collaborate, experience freedom!

DESIGN STORY: MATHEMATICAL CREATIVITY

# DESIGN STORY: MATHEMATICAL CREATIVITY

The Mathematical Creations Project

Part 1: Define a New Concept from Geometry

Part 2: Find as many properties as you can for your New Concept

# Definition

Caterpillar is made up of interlocking circles with their centers in a straight line. The edge of one circle is at the center of the next.

Herieth Ringo, Theodore Van Dyke

# 3. Computing the area of the biconcave-like regions
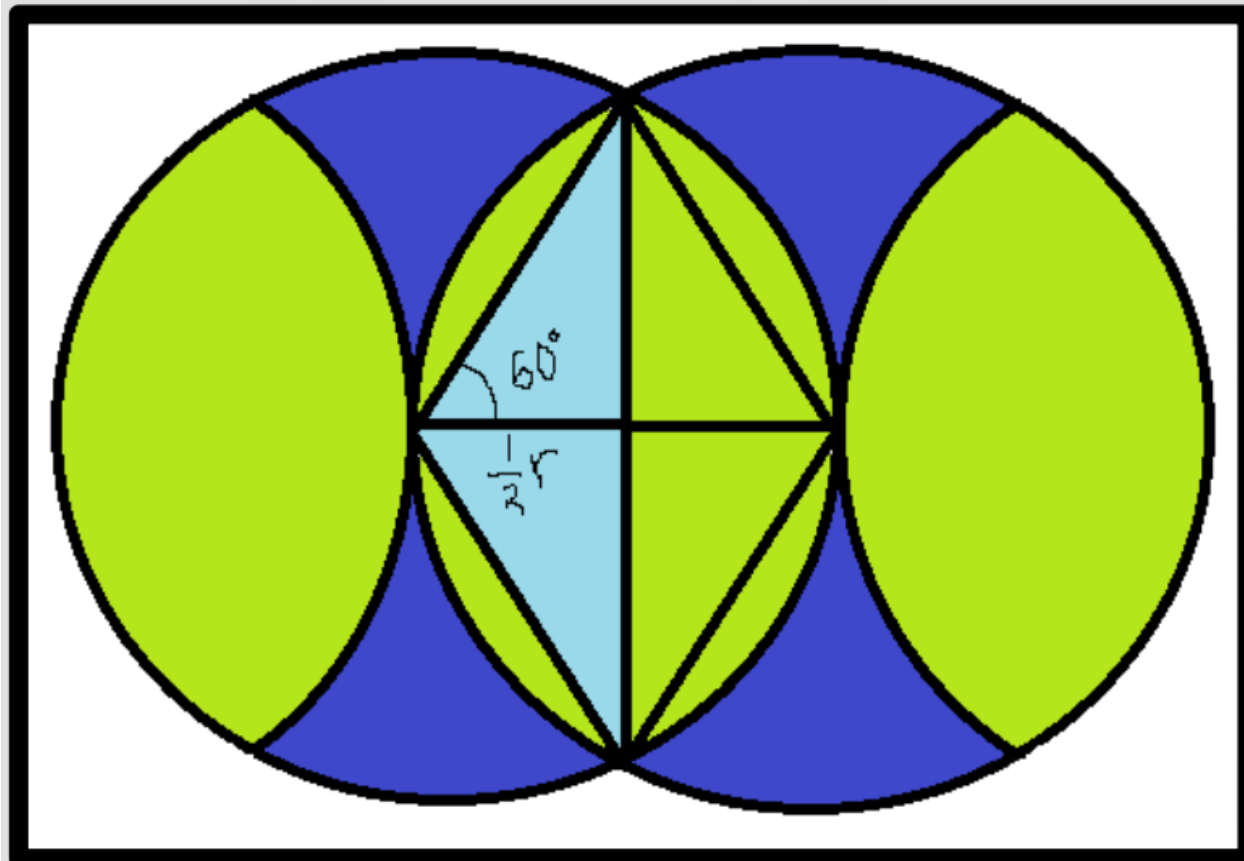


**Area of one biconcave-like figure**

= ½(Area of two interlocking circles-3 overlap areas )

= ½(($r^2$(4/3π+ √3/2)-3($r^2$(2/3π- √3/2))

= ½((4/3)π$r^2$ + √3/2$r^2$)–3(2/3π$r^2$ - √3/2$r^2$))

= ½((4/3)π$r^2$+ √3/2$r^2$– 2π$r^2$ + 3√3/2$r^2$)

= ½(4√3/2$r^2$-2/3π$r^2$)

= $r^2$ (Tan 60° -1/3π )

Herieth Ringo, Theodore Van Dyke

# Kepler's Conjecture

- Spherical balls of the same size can only fill 74% of the box or container. What about interlocking spherical balls? What if we think of interlocking spherical balls in the lens of interlocking circles?

Herieth Ringo, Theodore Van Dyke

# DESIGN STORY: MATHEMATICAL CREATIVITY

## The Mathematical Creations Project
Part 1: Define a New Concept from Geometry
Part 2: Find as many properties as you can for your New Concept

It definitely had the feeling that you could kind of get a personal grasp on what it is a little bit, like a touch on the wrist, of what it is like to be a mathematician. Like you kind of step into your own world of being creative and thinking like a mathematician. You have to come up with new concepts and not just being like "these are these mathematicians that come up with these new concepts" and were kind of put off by it. You actually get to experience it... it's pretty cool.

be flexible

"We bring imagination into our work by thinking of new and different ways to engage the **particular group of students we are teaching at a given moment in time**."
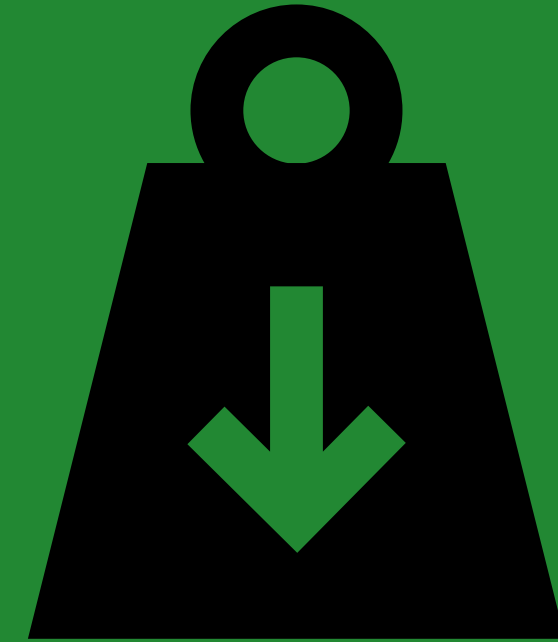
understandings

assessments

activities

# listening to students

**OR**

STRUGGLE

reasonable requests

RESISTANCE

counterproductive demands

"The assumption that it's your responsibility to remove student resistance completely overlooks the fact that **resistance is a natural rhythm of learning**. Any time you push students to confront complexity, increase their skill level, or think more critically you're going to get substantial pushback. To interpret that as a sign of bad teaching is insane. In fact, **if you're not getting resistance, you're probably not doing your job.** Your responsibility is not just to support students but also challenge them."
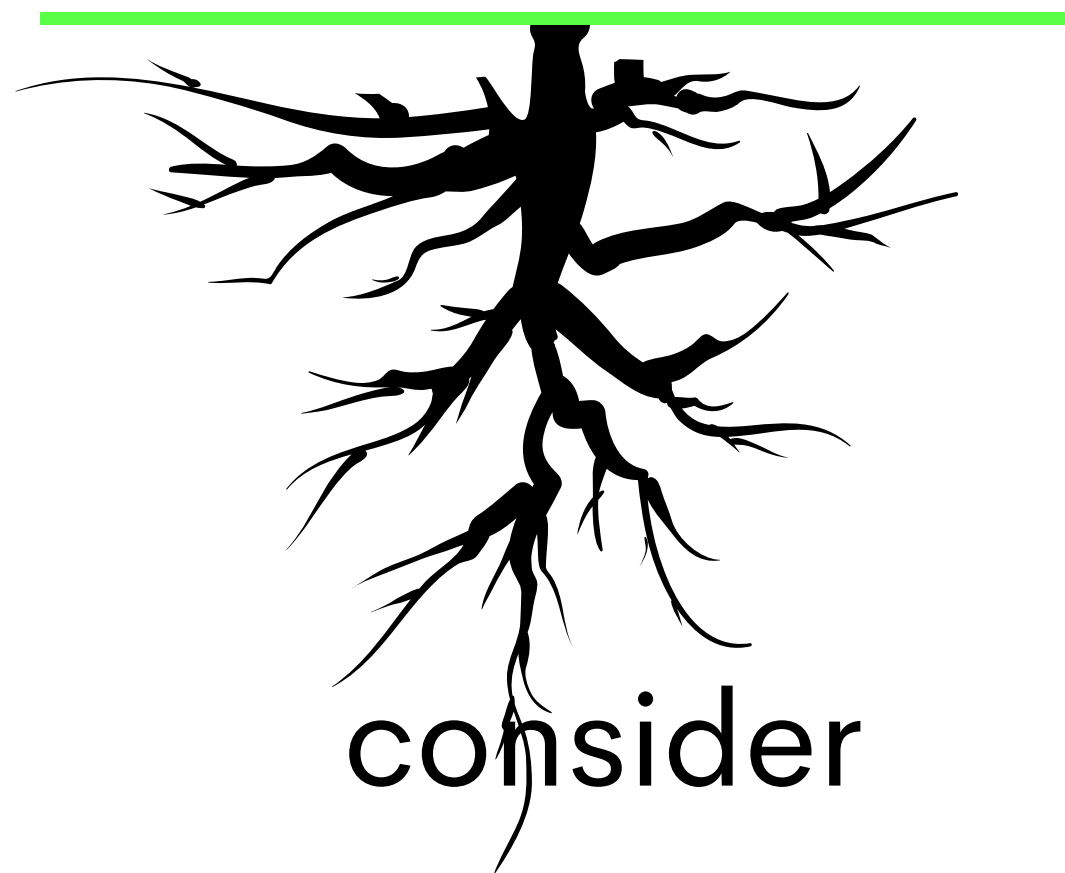
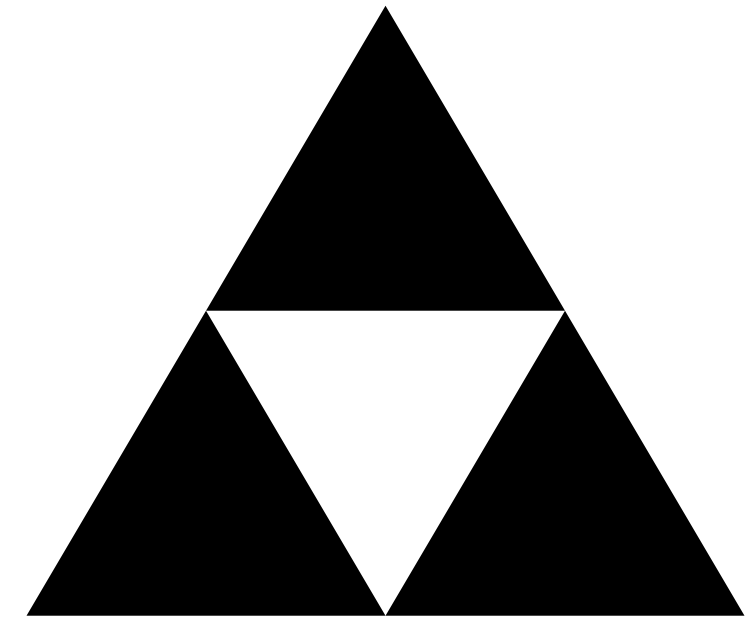STEPHEN BROOKFIELD, BECOMING A CRITICALLY REFLECTIVE TEACHER

# how I'm working to see if changes are necessary.
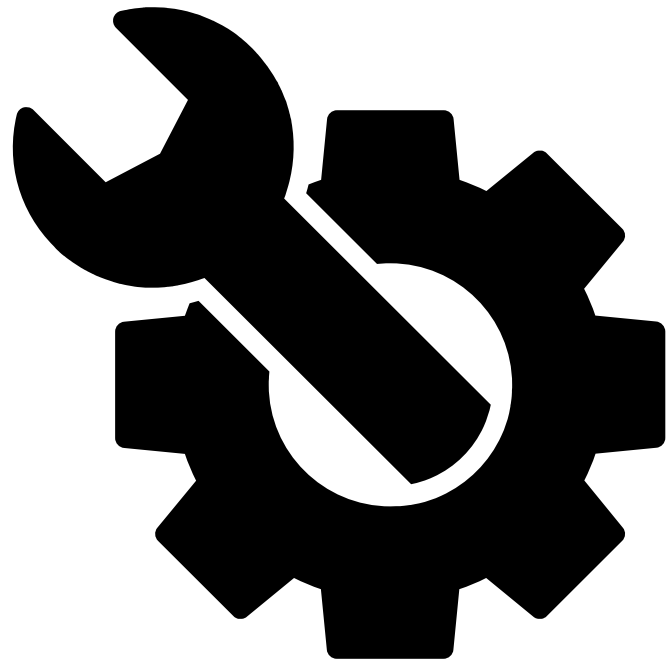
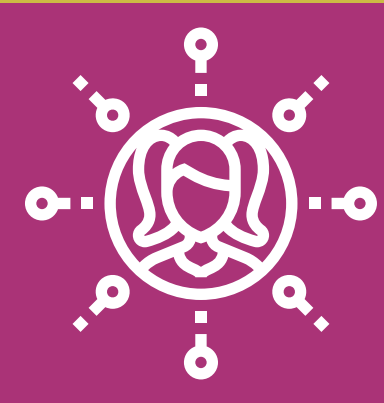Critical Incident Questionnaires

consider learning goals

asking community for advice

follow best practices

student-centred learning

focus on conceptual understanding & motivation

show care, tolerence for errors

seek buy-in from colleagues to offer regularly

"**Good teachers, like good midwives, empower**.  Good teachers know when to hang back and remain silent, when to watch and wonder at what is taking place all around them. They can push and they can pull when necessary – just like midwives – but they know that they are not always called upon to perform.  **Sometimes the performance is and must be elsewhere**, sometimes the teacher can feel privileged just to be present at the drama happening nearby."

"Guides show people the way, and sometimes they even go along, but **guides do not make the trek for the traveler**.  Guides point out the sites; they do not experience the excitement of seeing them for the first time.  **Guides offer advice, point out the pitfalls, and do their best to protect, but it is not within their power to prevent accidents.**"

WEIMER, LEARNER-CENTRED TEACHING, WEIMER

# be a knowledge diplomat

"The diplomacy of knowledge[:] the willingness and ability to work across disciplinary boundaries, cultural barriers, and international borders to uncover, share, and refine knowledge."
– David Johnston,*Trust*

# be a knowledge diplomat

"The diplomacy of knowledge[:] the willingness and ability to work across disciplinary boundaries, cultural barriers, and international borders to uncover, share, and refine knowledge."

"... the surest way to promote peace, spread prosperity, and build trust among all the people of the world."

## SHAPE

Presentations can be used as lectures and more.

## COLOR

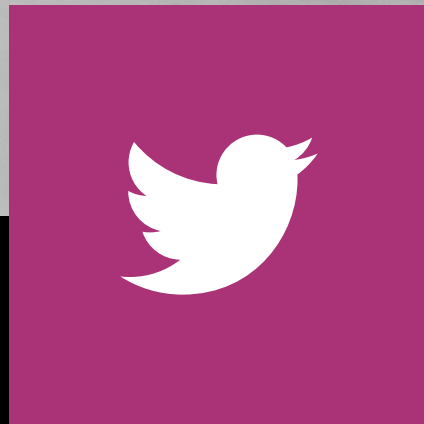Presentations can be used as lectures and more.

## PURPOSE

Presentations can be used as lectures and more.

Presentations are communication tools that can be used as demonstrations, lectures, speeches, reports, and more. Most of the time, they're presented before an audience.

# TWITTER

Presentations can be used as lectures and more.

# FACEBOOK

Presentations can be used as lectures and more.

# INSTAGRAM

Presentations can be used as lectures and more.

## MAILING ADDRESS

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(123) 456 7890

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