Fostering engagement through interdisciplinary projects, collaborative teams, and scaffolded autonomy:

Making math for everyone (and especially for engineers)

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Setting the stage…

Olin College of Engineering

Opened in 2002 with a mission to change engineering education

~380 students; all major in engineering

~40 faculty; no departments

Intentional about pedagogy

Commonly used pedagogical theories

Active learning

Universal Design for Learning (UDL)

Fostering intrinsic motivation

Necessary conditions for positive motivation and learning

Psychologists Deci and Ryan identified necessary conditions for positive motivation (2000, 2002, 2008, 2017)

Autonomy	• Sense of choice, control
Competence	• Sense of progress towards mastery
Relatedness	• Socially invested in collaborations

Common curriculum-design elements

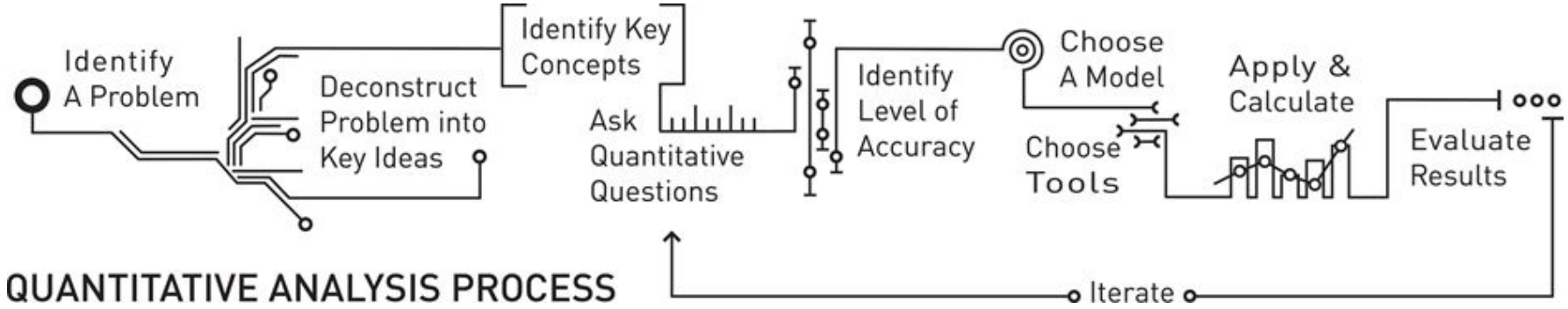
- Faculty role as experience designer
  - Who are the students in the room?
  - What do they need to feel engaged?
  - What knowledge, skills, tools, behaviors do they need to develop?
- Faculty role as classroom guide/facilitator
- Intentional teaming experiences
- Interdisciplinary / hands-on projects
- Meaningful choices with increasing autonomy
- Deliberate community-building

The Olin Curriculum: common elements in the first two years

1st Year Fall	1st Year Spring	2nd Year Fall	2nd Year Spring
QEA 1 (Math/Sci/Eng)	**QEA 2 (Math/Sci/Eng)**	***QEA 3 (Math/Sci)***	***QEA 4 (Signals or Dynamics)***
Design Nature (Eng)	**Products and Markets (Entrepreneurship)**	**Principles of Integrated Engineering (Eng)**	**User-Oriented Collaborative Design (Eng)**
Modeling and Simulation (Math/Sci)	**Sensors and Measurement (Eng)**	***Discrete Math***	Often a major-related engr course
AHS Foundation	Often Software Design or Mechanical Design	Often a Science/AHS	Often a Science/AHS

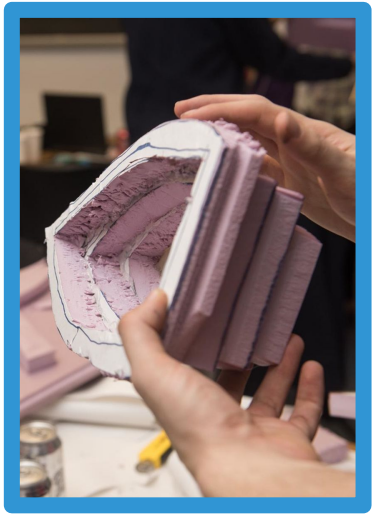
Quantitative Engineering Analysis

Students experience ALL of the quantitative analysis process

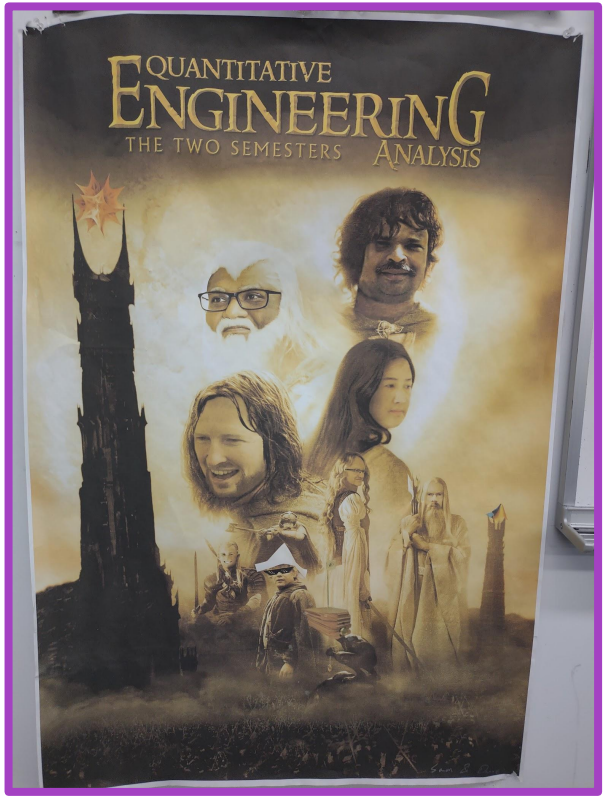


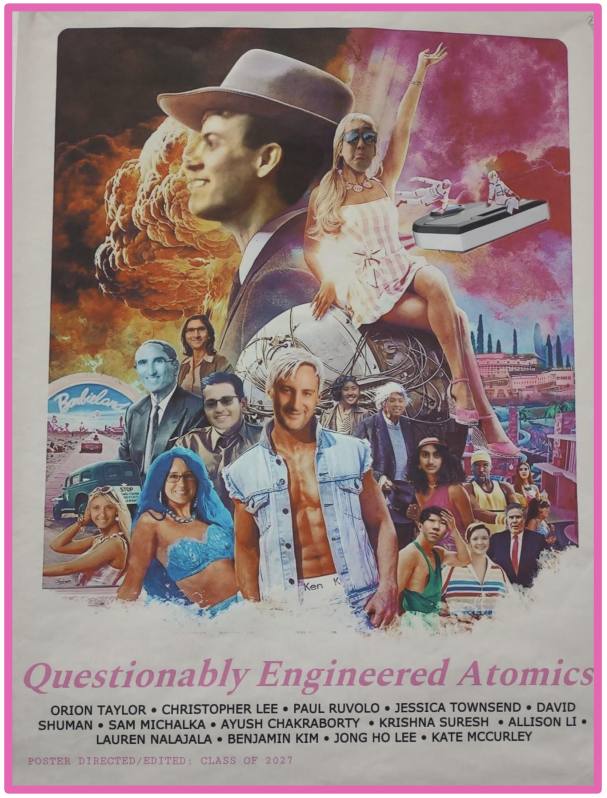
Quantitative Engineering Analysis: Objectives

- competence and skill with mathematics and physics tools in an engineering design context
- ability to build, tune, and interpret mathematical models of physical and information objects
- resource finding skills: learning how to learn about quantitative topics
- self-efficacy and willingness to use quantitative analysis tools
- shared understanding, approach, and language for quantitative analysis among mathematics, physics and engineering faculty

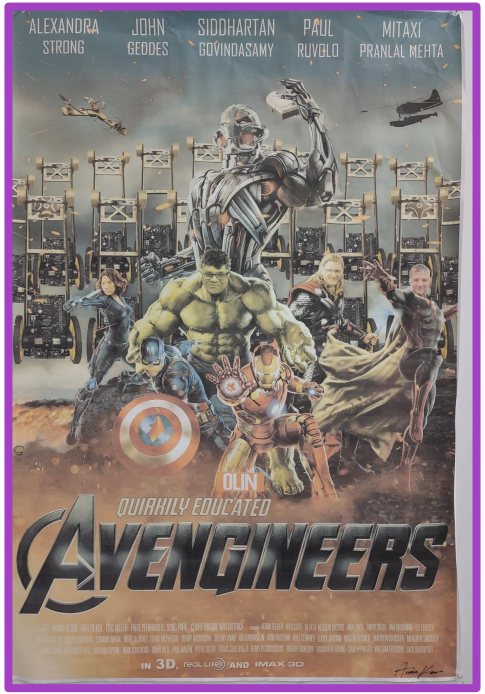


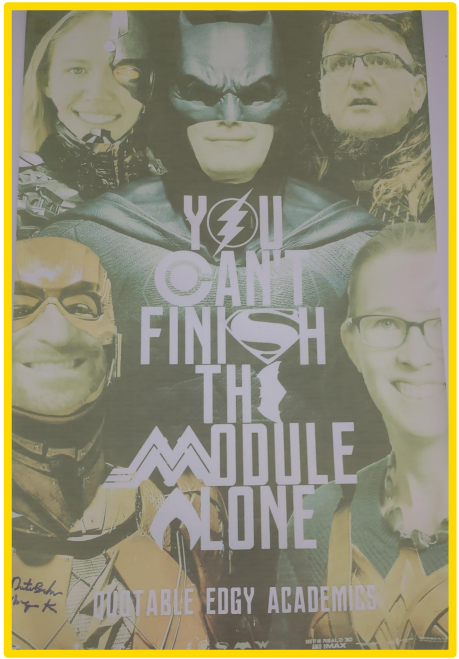
QEA: Interdisciplinary faculty team

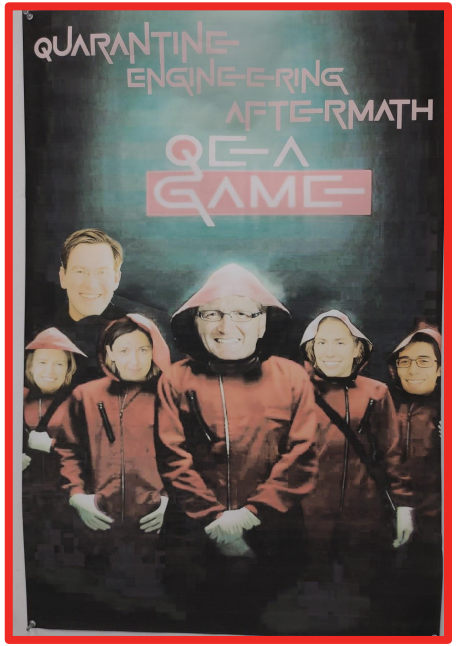




Faculty team: always evolving







QEA: Studio classroom

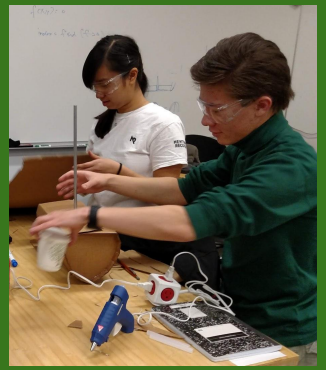
- Table discussions; faculty as guide
- Every meeting counts
- Make learning visible
- Classroom community and camaraderie

Four design principles for QEA courses

1. Demonstrate relevance through context
2. Identify key content to teach; facilitate lifelong learning for the rest
3. Use physical artifacts to build intuition and validate calculations
4. Promote peer learning through shared spaces and experiences

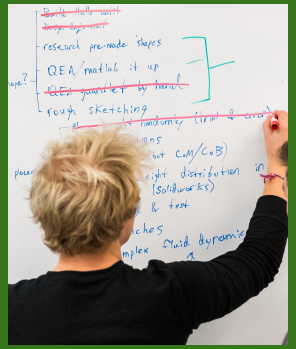
Typical components of a QEA module

Kickoff



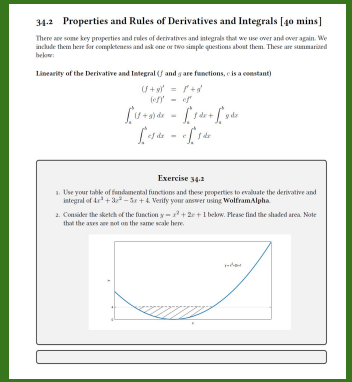
- Engaging activity
- Demonstration

Framing



- Process breakdown
- Concept mapping
- Content introduction

Skill building



34.2 Properties and Rules of Derivatives and Integrals [40 mins]

There are some key properties and rules of derivatives and integrals that we use over and over again. We include them here for completeness and ask one or two simple questions about them. These are summarized below:

Linearity of the Derivative and Integral (f and g are functions, c is a constant)

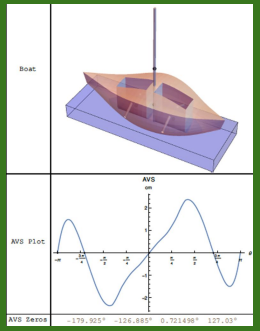
$$(f+g)' = f'+g'$$
$$(cf)' = cf'$$
$$\int_a^b (f+g)\,dx = \int_a^b f\,dx + \int_a^b g\,dx$$
$$\int_a^b cf\,dx = c\int_a^b f\,dx$$

Exercise 34.2

1. Use your table of fundamental functions and these properties to evaluate the derivative and integral of $4x^3+3x^2-5x+4$. Verify your answer using **WolframAlpha**.
2. Consider the sketch of the function $y = x^2+2x+1$ below. Please find the shaded area. Note that the axes are not on the same scale here.

- Mathematics and science reading and exercises
- Applications to relate concepts to topics outside of the project theme
- Connections to other applications

Project work



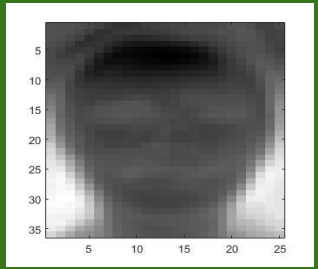
- Goal setting
- Shared work time
- Peer support

Project share-out

- Student demo
- Presentation
- Report
- Reflection

Example QEA modules

Facial recognition



linear algebra
data analysis

Boat design

calculus
mechanics

Robot navigation

optimization/ gradients
rigid body mechanics

Baby Warmer (Astopad)

thermal modeling
ODEs
control systems

Discrete Math

Combinatorics & Graph Theory

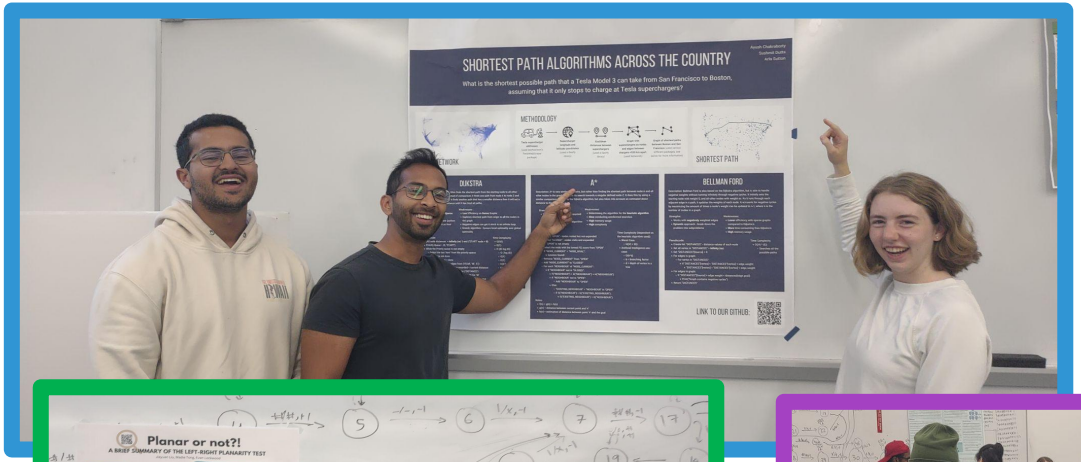
Taken by ~⅔ of our students

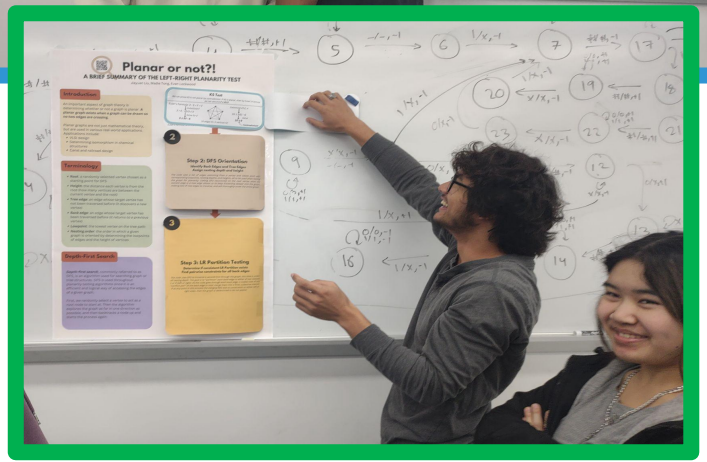
Fostering intrinsic motivation in Discrete Math

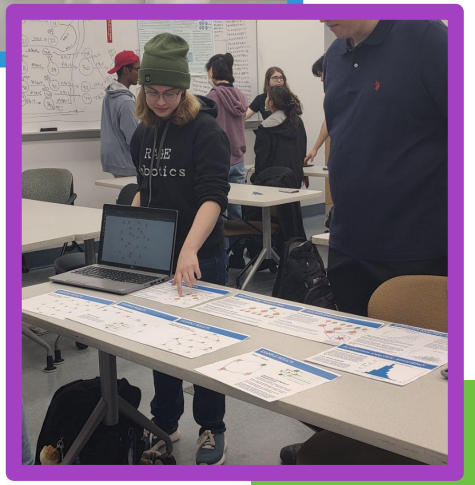
Making a required course feel more like a choice…

Autonomy	Choose topics for projects; choose deliverables for certain assignments
Competence	Students can craft a personalized level of challenge through most assignments
Relatedness	Build student community through scaffolded group work; table talks with professor

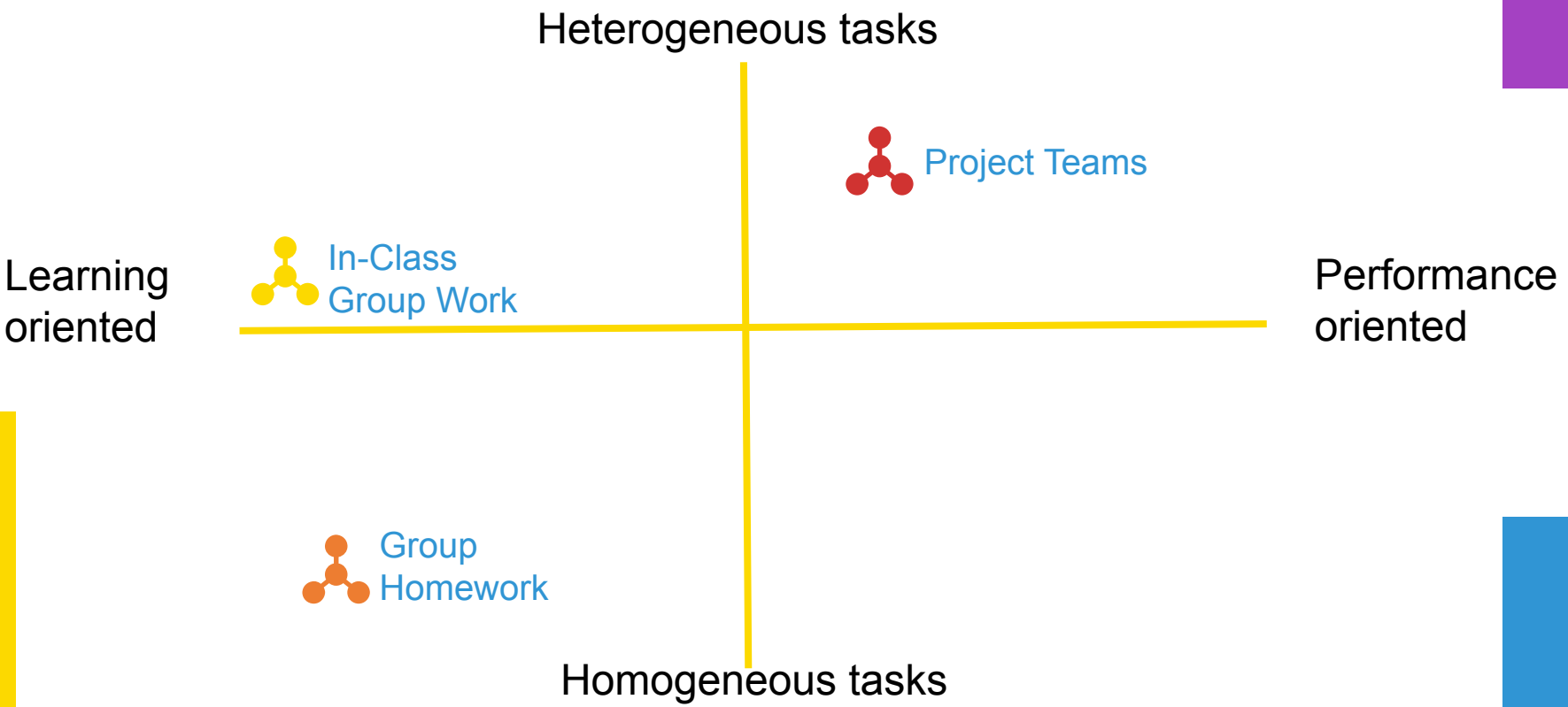
Scaffolded autonomy: What to learn, how to learn it, how to demonstrate learning



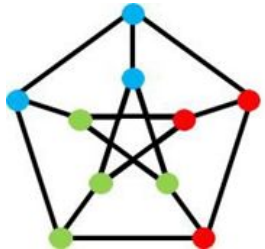


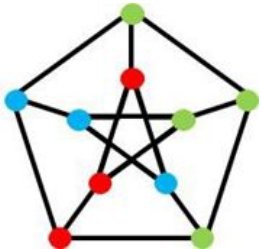


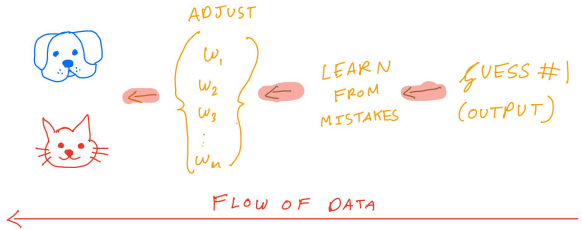
Relatedness: Building community and collaboration

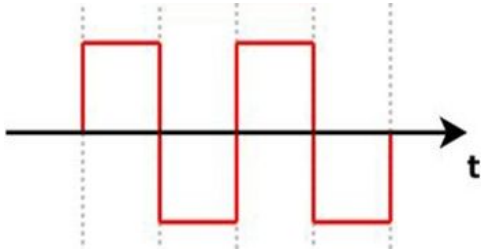


Interdisciplinary projects as culminating teaming experience

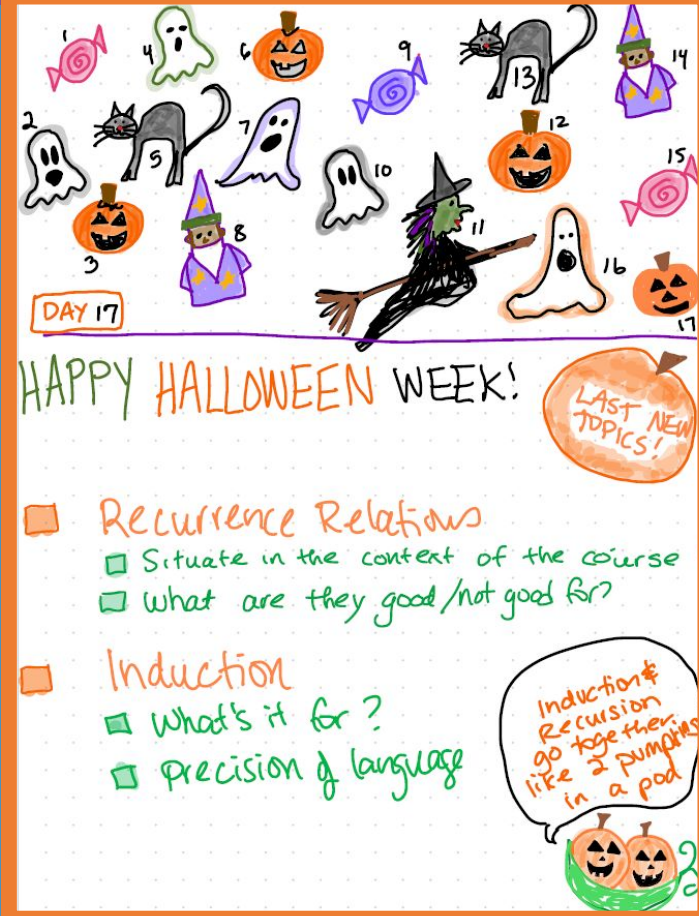


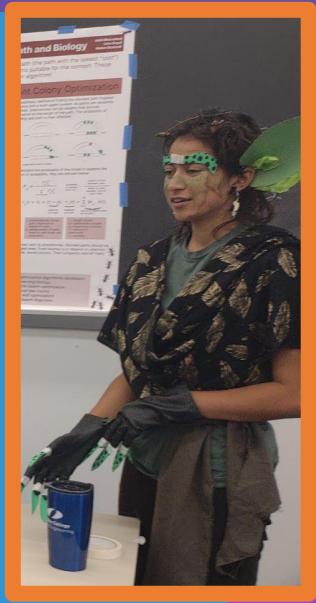






Keeping math joyful, collaborative, and fun





Main takeways

- Faculty role as experience designer
  - Who are the students in the room?
  - What do they need to feel engaged?
  - What knowledge, skills, tools, behaviors do they need to develop?
- Faculty role as classroom guide/facilitator
- Intentional teaming experiences for the students
  - Consider your goals as you design team/group work
- Interdisciplinary / hands-on projects
- Consider ways to incorporate meaningful choices, autonomy
- Building community and camaraderie are keys to engagement, enjoyment, and learning (for students and faculty!)

Q&A

Thank you for coming, and thank you to Tara and Brendan for hosting!