

# science, education, computing, community...in ten(ish) minutes

michigan state university  
13 sept 2023

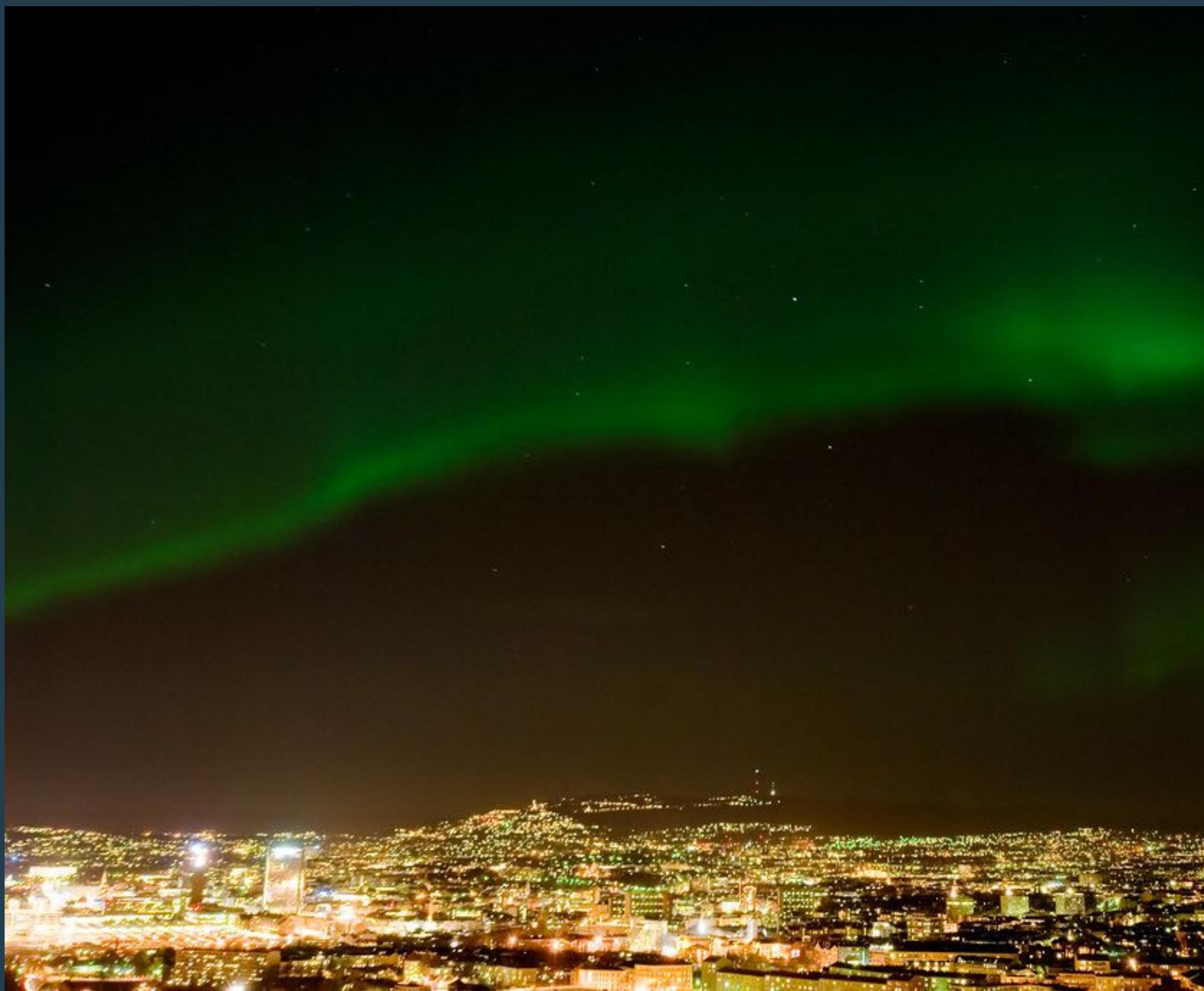
**danny caballero (he/him)**

*department of physics and astronomy*

*department of computational mathematics, science, and engineering*

*create for stem institute*





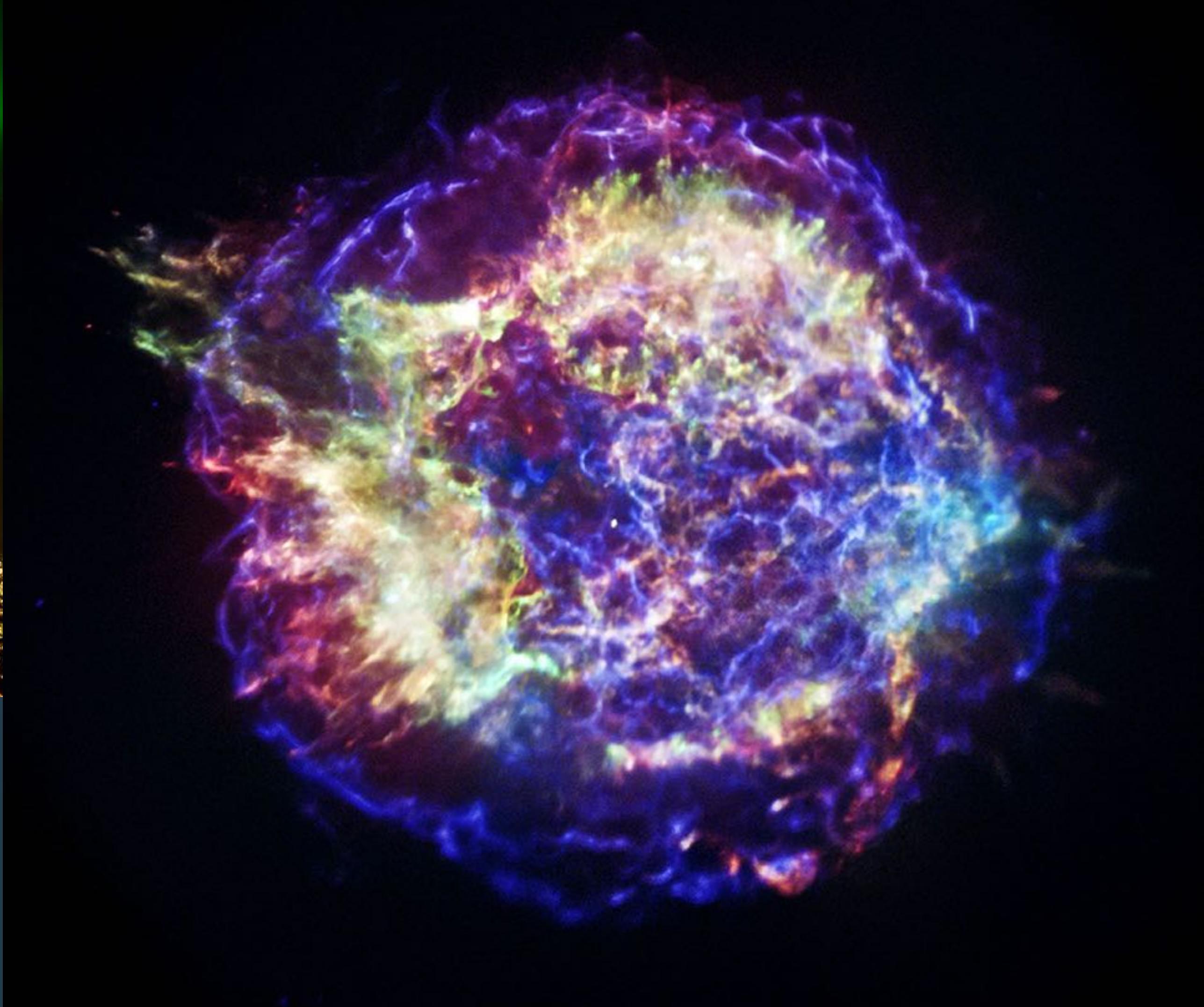
aurora borealis over oslo

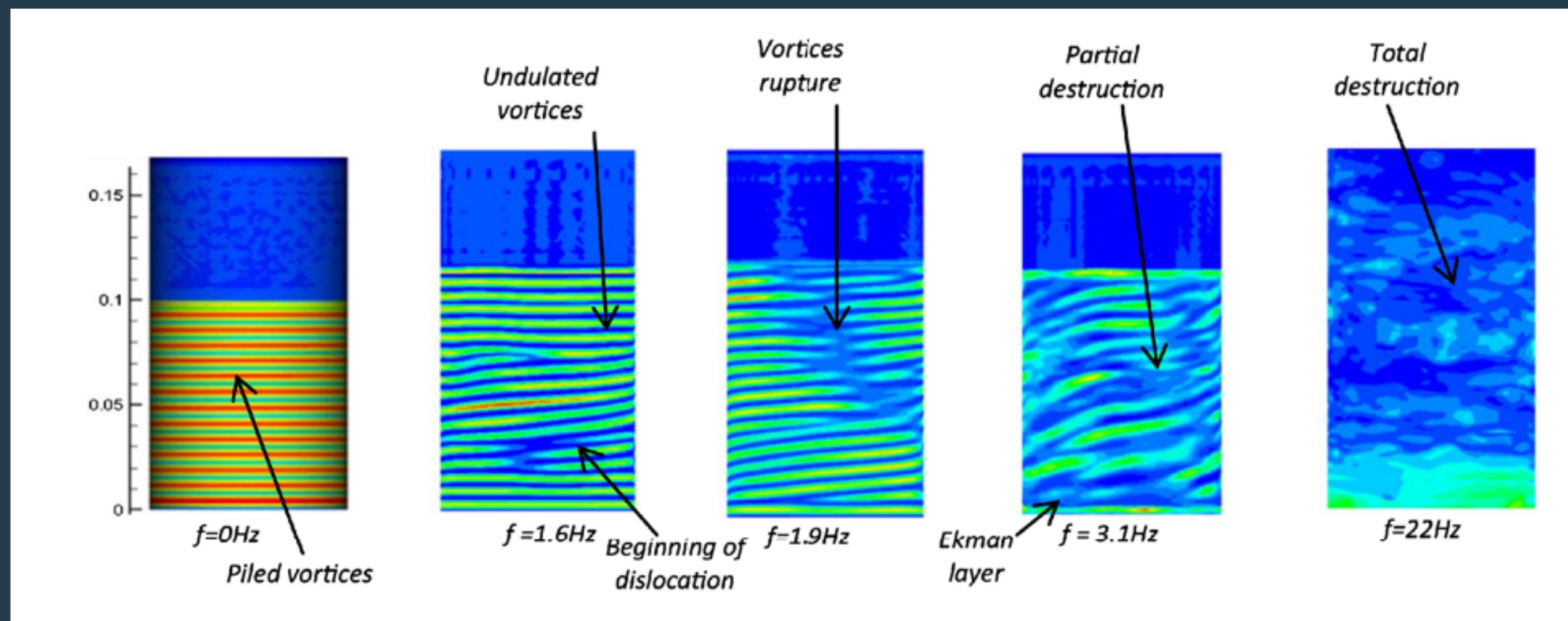
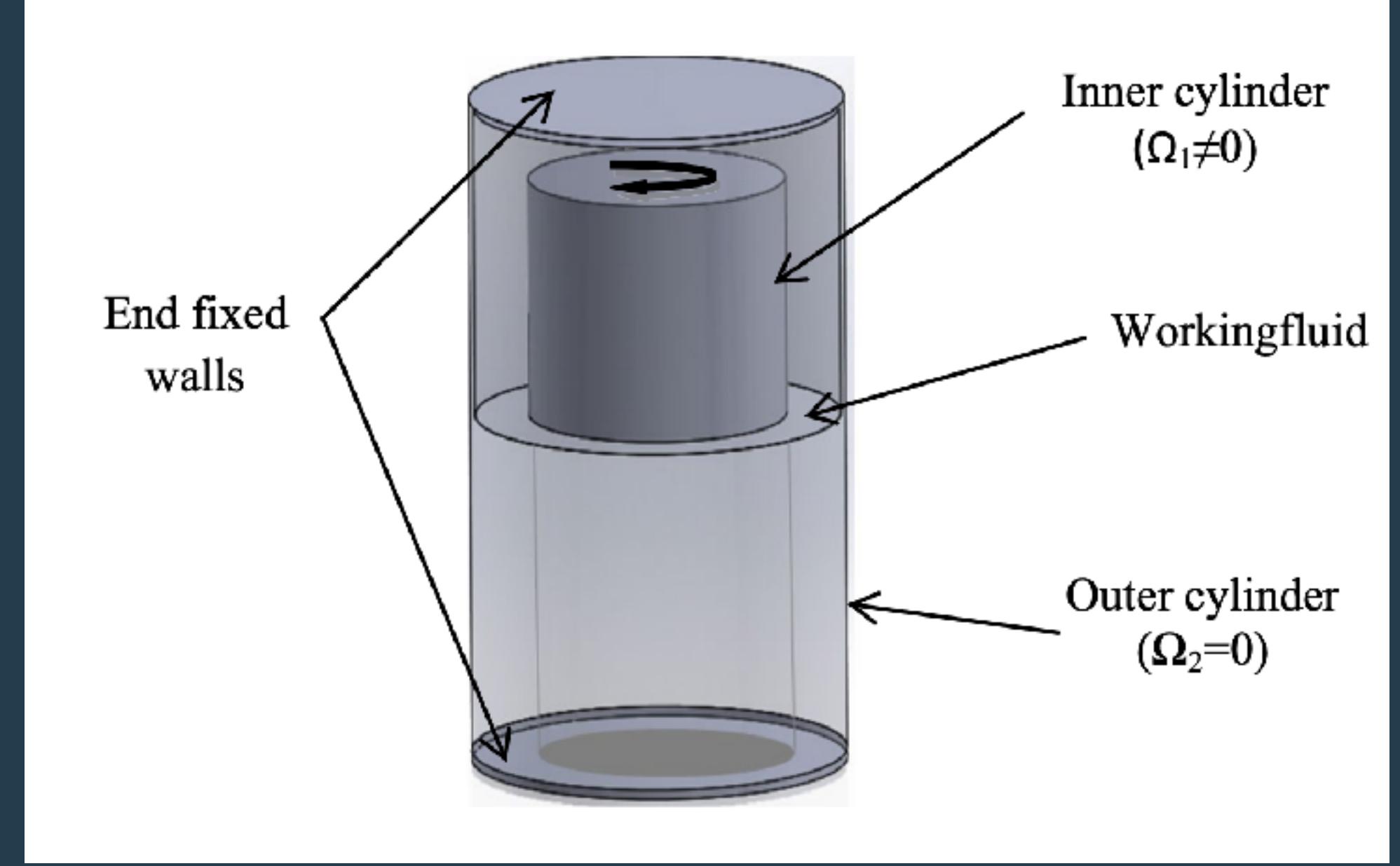
<https://www.flickr.com/photos/65218245@N00/326627830>

science can explain  
natural phenomena

supernova remnant - cassiopeia a

[https://www.nasa.gov/mission\\_pages/chandra/multimedia/exploring-cassiopeiaA.html](https://www.nasa.gov/mission_pages/chandra/multimedia/exploring-cassiopeiaA.html)





taylor-couette cylinder & transition to turbulence

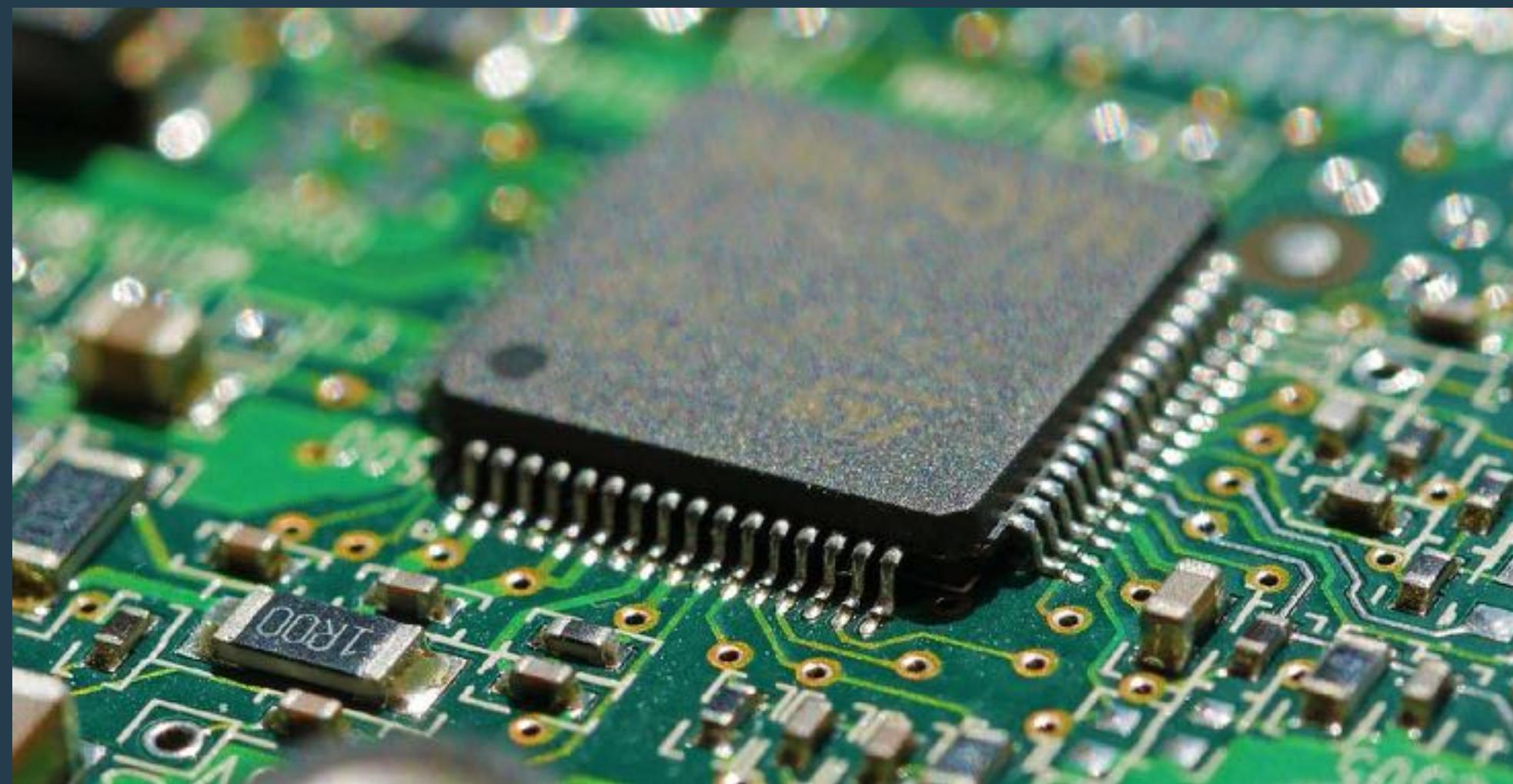
Abdelali, A., et al. *Journal of the Brazilian Society of Mechanical Sciences and Engineering* 41.6 (2019): 259.

natural transition to turbulent flow

<https://www.flickr.com/photos/22493175%40N02/50000447596>

science can satisfy  
human curiosity

# science can benefit society



# framing my research

all folks can develop a deep understanding of science

all folks can develop a positive stance towards science

all folks can shape the work and practice of science

# framing my research

all folks can develop a deep understanding of science

all folks can develop a positive stance towards science

all folks can shape the work and practice of science

we discover, design, and develop the conditions  
and environments in which all folks who are  
learning science can thrive

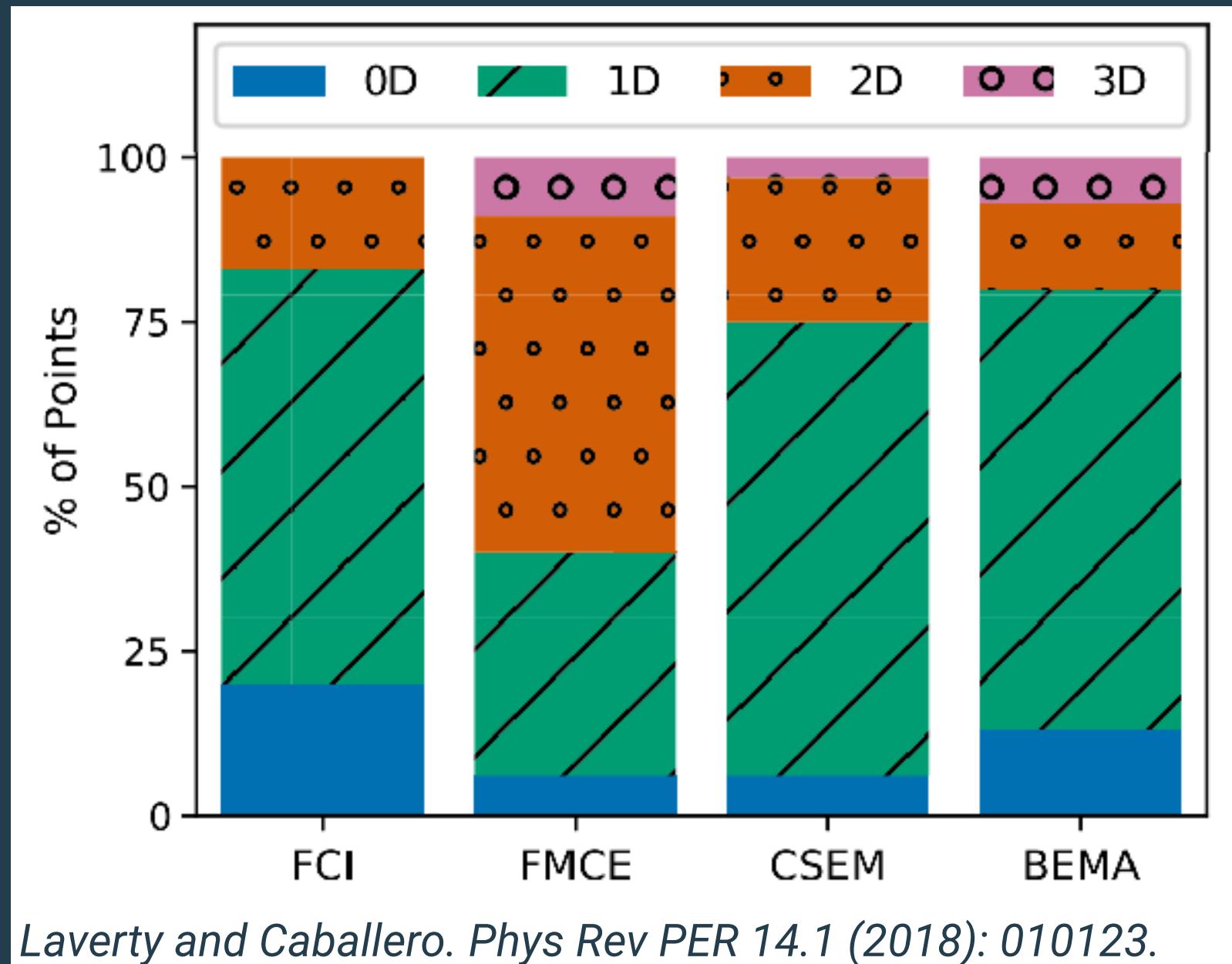
# moving beyond active learning

three-dimensional learning observation protocol (3DLOP)



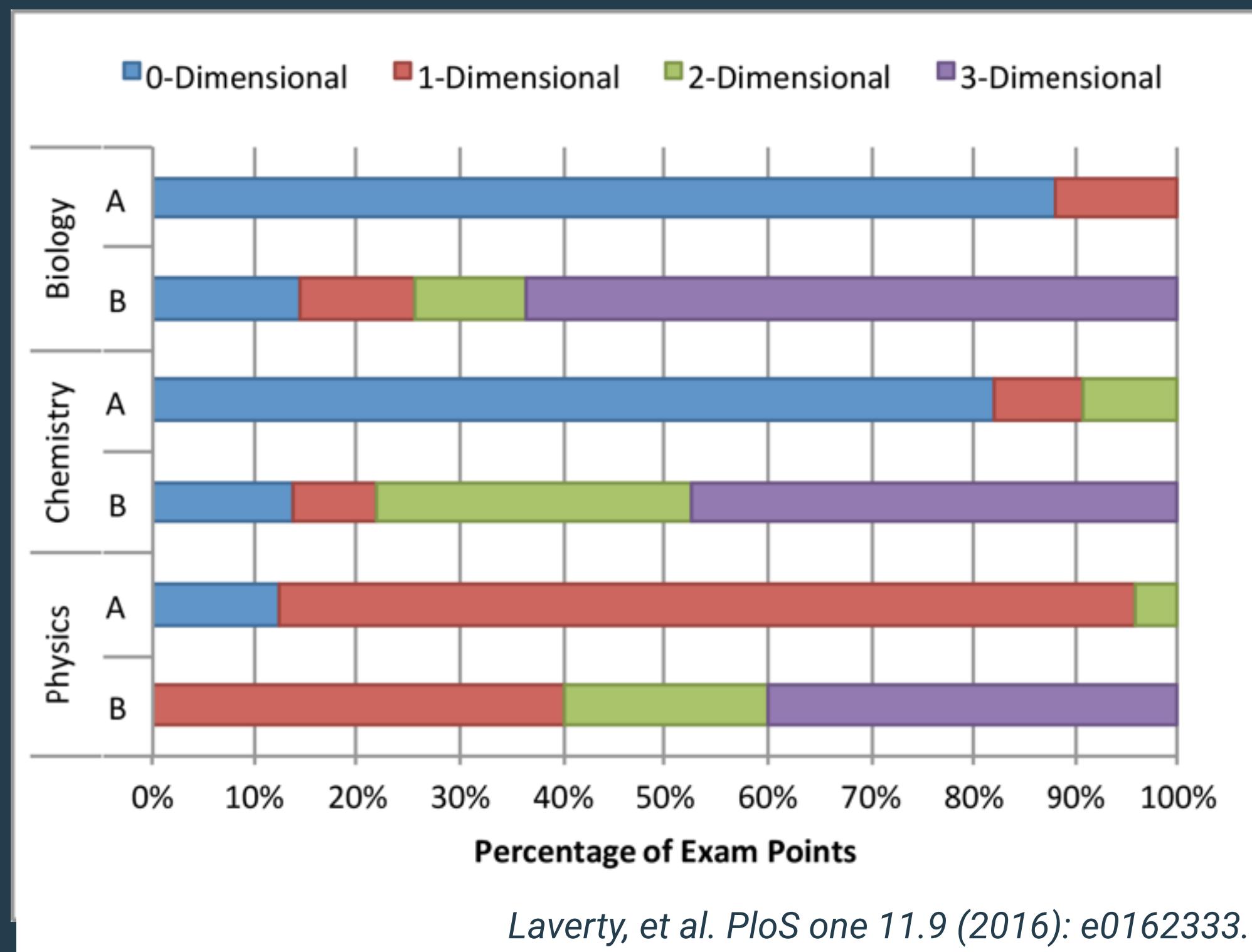
Topics	Admin	Review: Gravity, Potential Energy, Circular Motion	Intro to Kepler's Laws	Kepler's First Law	Kepler's Second Law	Kepler's Third Law	Synthesizing Kepler's Laws	
Teaching Activities	Admin	CQ CQ CQ	Lecture			CQ CQ	CQ CQ CQ CQ	Lecture
SP		None	None	None	None	None	None	
CI		-	-	-	-	-	-	
CC		-	-	-	-	-	-	

Bain, et al. PLoS One 15.6 (2020): e0234640.



Laverty and Caballero. Phys Rev PER 14.1 (2018): 010123.

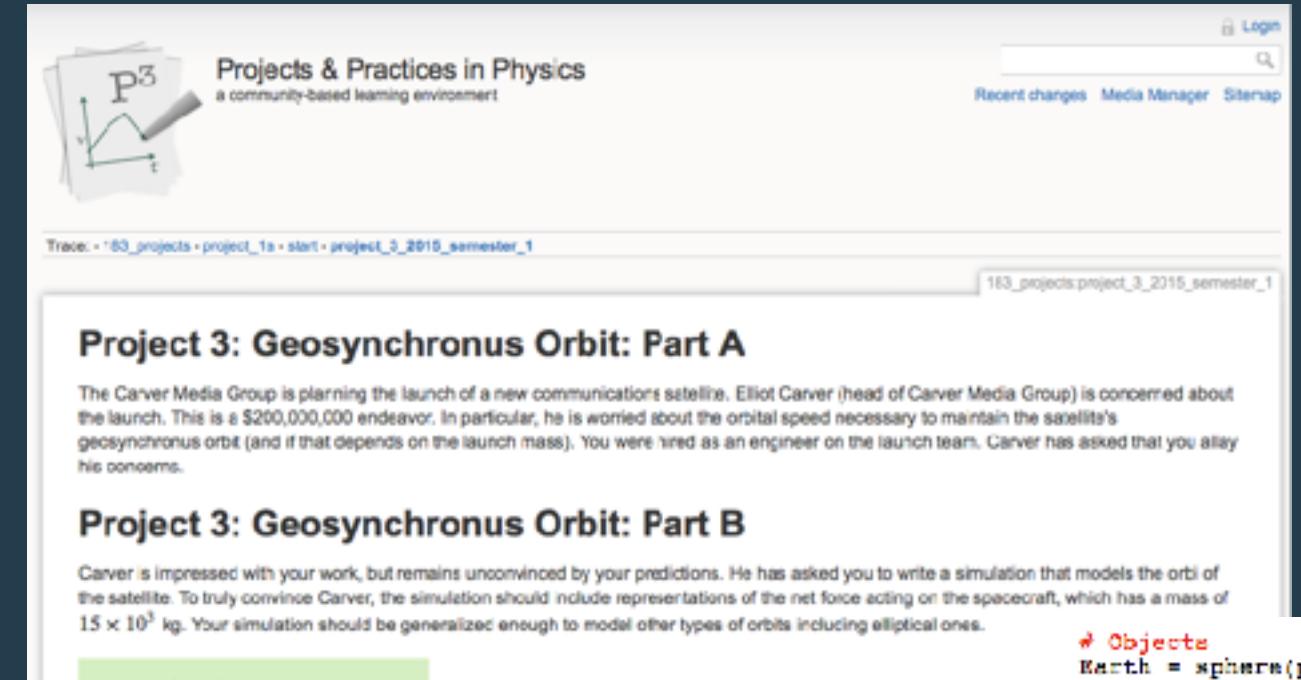
active learning is  
not necessarily  
3d learning



Laverty, et al. PloS one 11.9 (2016): e0162333.

# developing community-based courses

## projects and practices in physics



Project 3: Geosynchronous Orbit: Part A

The Carver Media Group is planning the launch of a new communications satellite. Elliot Carver (head of Carver Media Group) is concerned about the launch. This is a \$200,000,000 endeavor. In particular, he is worried about the orbital speed necessary to maintain the satellite's geosynchronous orbit (and if that depends on the launch mass). You were hired as an engineer on the launch team. Carver has asked that you allay his concerns.

Project 3: Geosynchronous Orbit: Part B

Carver is impressed with your work, but remains unconvinced by your predictions. He has asked you to write a simulation that models the orbit of the satellite. To truly convince Carver, the simulation should include representations of the net force acting on the spacecraft, which has a mass of  $15 \times 10^3$  kg. Your simulation should be generalized enough to model other types of orbits including elliptical ones.

# Objects  
Earth = sphere(pos=vector(0,0,0), radius=6.4e6, material=materials.BlueMarble)  
Satellite = sphere(pos=vector(7\*Earth.radius, 0, 0), radius=1e6, color=color.red, make\_trail=True)

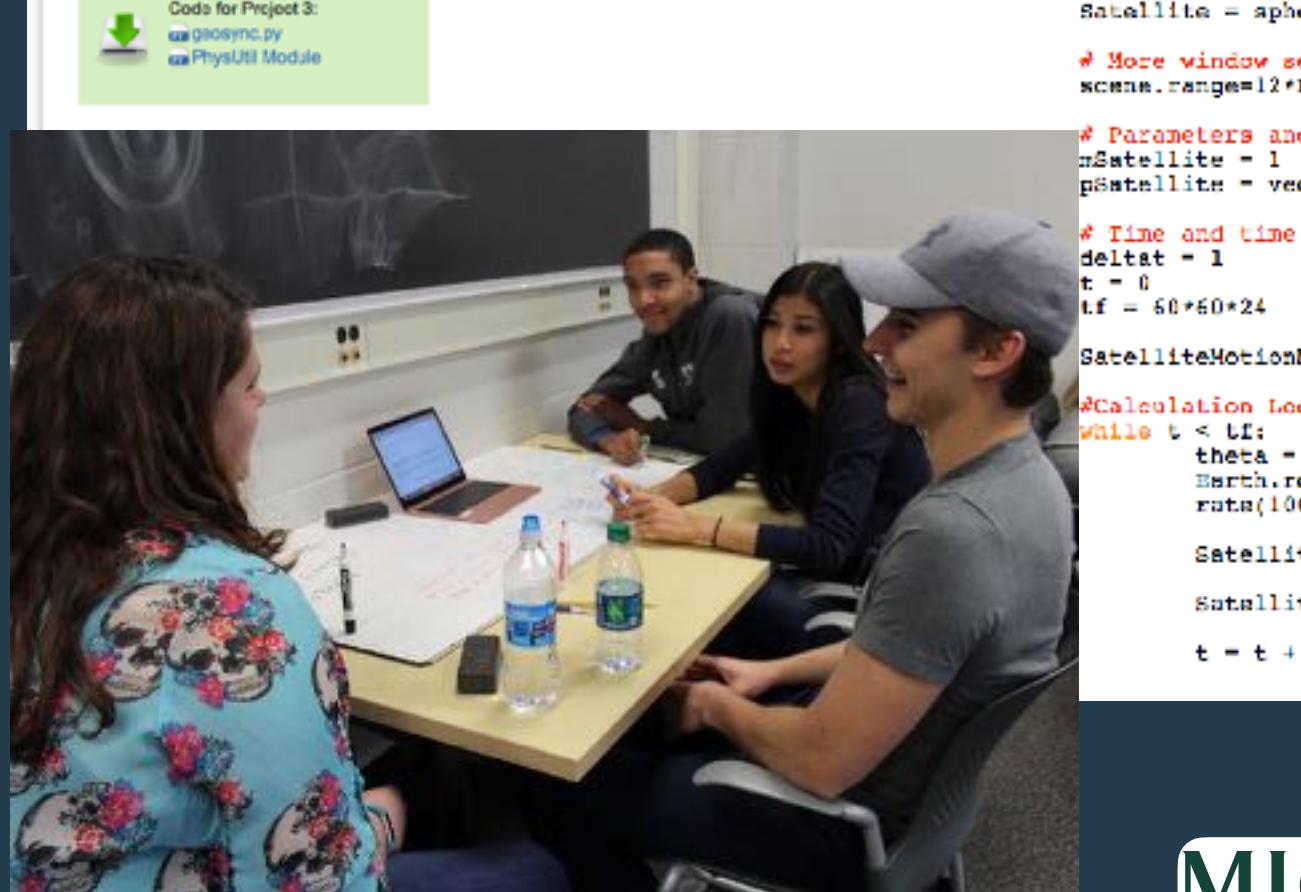
# More window setup  
scene.range=12\*Earth.radius

# Parameters and Initial conditions  
mSatellite = 1  
pSatellite = vector(0,5000,0)

# Time and time step  
deltat = 1  
t = 0  
tf = 60\*60\*24

SatelliteMotionMap = MotionMap(Satellite, tf, 20, markerScale=2000, labelMarkerOrder=False)

#Calculation Loop  
while t < tf:  
 theta = (.25e-5) \* deltat # IGNORE THIS LINE  
 Earth.rotate(angle=theta, axis=vector(0,0,1), origin=vector(0,0,0)) # IGNORE THIS LINE  
 rate(10000)  
  
 Satellite.pos = Satellite.pos + pSatellite/mSatellite\*deltat  
 SatelliteMotionMap.update(t, pSatellite/mSatellite)  
  
 t = t + deltat

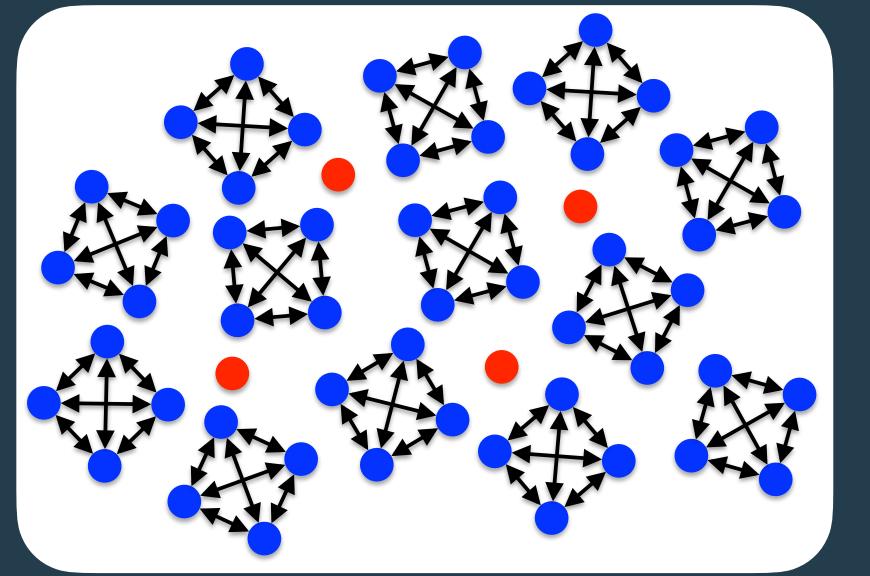


group-based

- Irving, Obsniuk, & Caballero, EJP (2017)  
Pawlak, Irving, & Caballero, Phys. Rev. PER (2020)  
Irving, McPadden, & Caballero Phys. Rev. PER (2020)



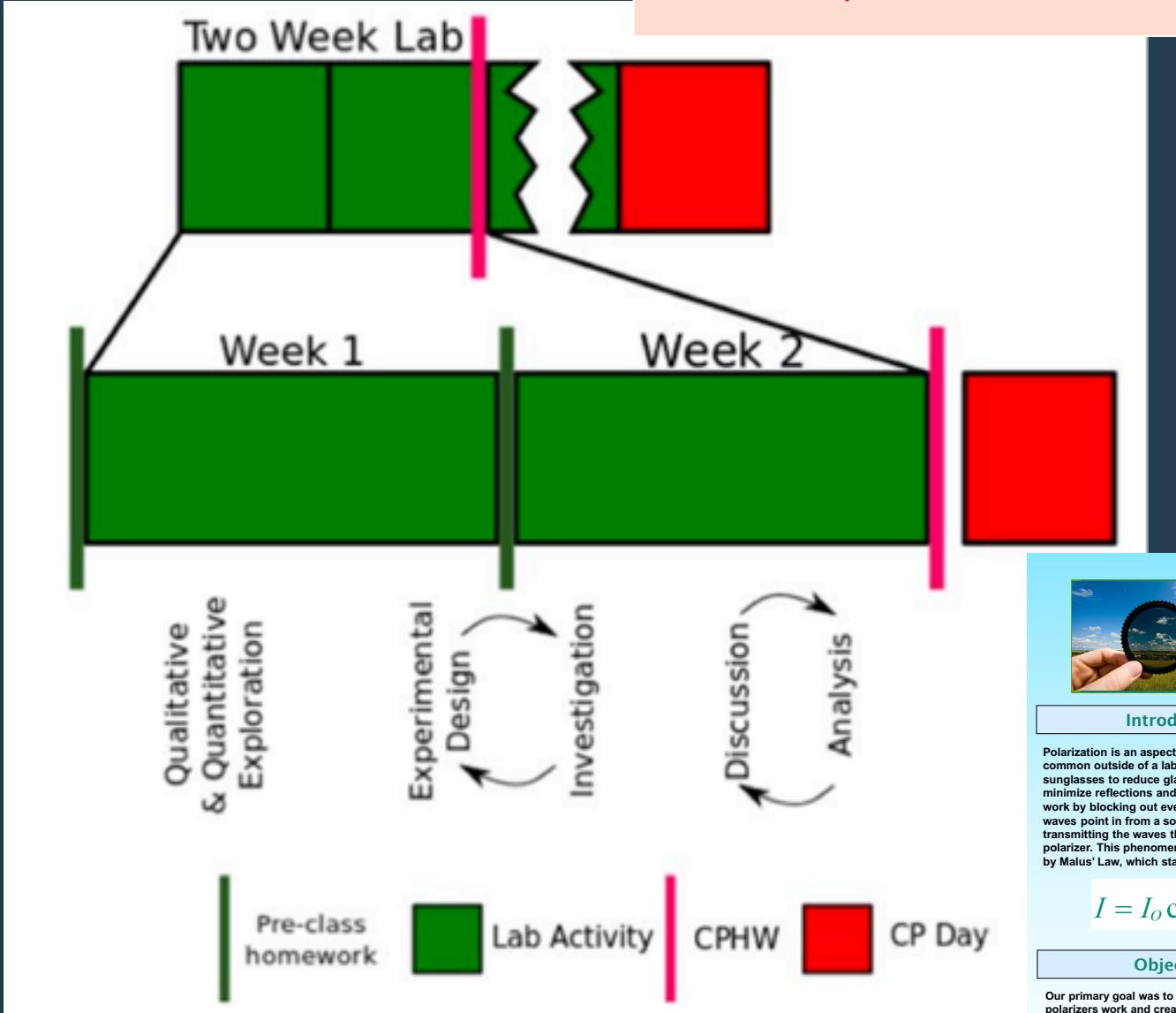
LAs



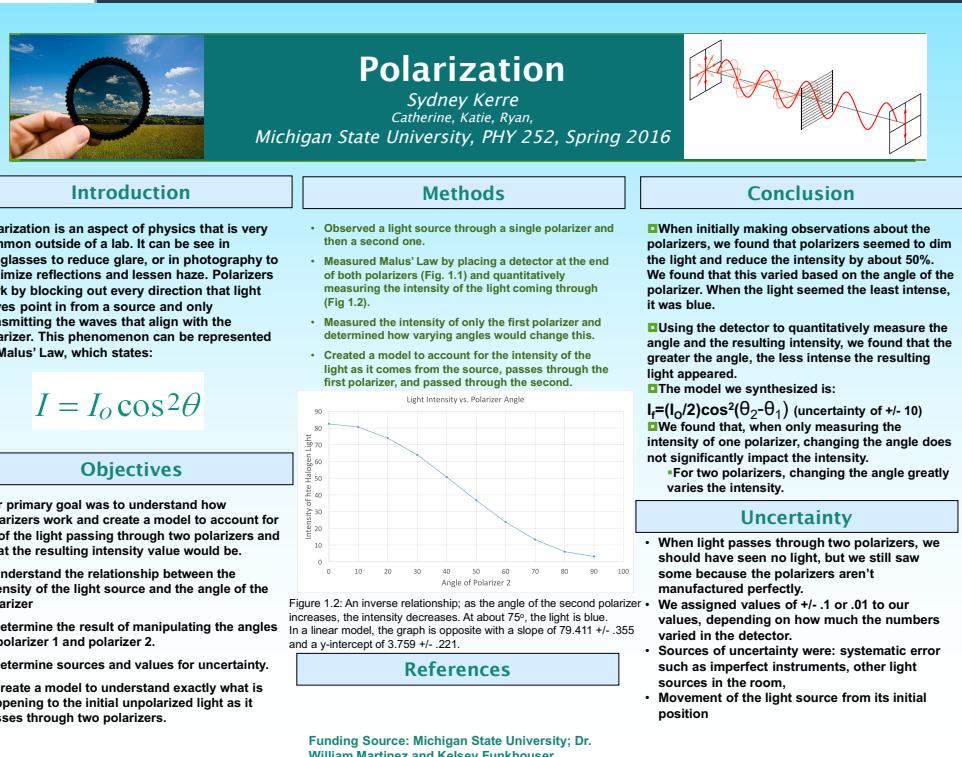
computing

## data lab

- Demonstrate understanding of uncertainty in measurements**
- Students should determine/estimate the inherent uncertainty in their measurement devices and how those uncertainties affect their results. This may progress through:
    - Developing estimates of uncertainty in the devices
    - Developing rough predictions for how the uncertainty in their device propagates through the system, assuming a linear proportionality
    - Developing precise predictions for how uncertainty contributed by measurement devices propagates through the system
  - Students should be able to distinguish between sources of systematic uncertainty and random error and quantifiably determine the values of each



longer  
investigatory  
labs & science  
communication



**Polarization**  
Sydney Kerre  
Michigan State University, PHY 252, Spring 2016

**Introduction**

Polarization is an aspect of physics that is very common outside of lab. It can be seen in sunglasses to reduce glare, or in photography to minimize reflections and lessen haze. Polarizers work by blocking out every direction that light waves travel except for the ones that are transmitting the waves that align with the polarizer. This phenomenon can be represented by Malus' Law, which states:

$$I = I_0 \cos^2(\theta - \theta_0)$$

**Methods**

When initially making observations about the polarizers work, we found that polarizers seemed to dim the light and reduce the intensity by about 50%. We found that this varied based on the angle of the polarizers. When the light seemed the least intense, it was blue.

Using the detector to quantitatively measure the angle and the resulting intensity, we found that the greater the angle, the less intense the resulting light.

We synthesized is:

$$I = I_0/2 \cos^2(\theta - \theta_0)$$

We found that, when only measuring the intensity of one polarizer, changing the angle does not significantly impact the intensity.

For two polarizers, changing the angle greatly varies the intensity.

**Uncertainty**

- When light passes through two polarizers, we should have seen no light, but we still saw some because the polarizers aren't made perfectly.
- We assigned values of +/- 1 or +/- 0.01 to our values, depending on how much the numbers varied in the detector.
- When we measured the intensity were: systematic error such as imperfect instruments, other light sources in the room, movement of the light source from its initial position

**Figure 1.2: An inverse relationship: as the angle of the second polarizer increases, the intensity decreases. At about 79°, the light is blue. In a linear model, the data is a straight line with a slope of 79.411 +/- .365 and a y-intercept of 3.799 +/- .221.**

**References**

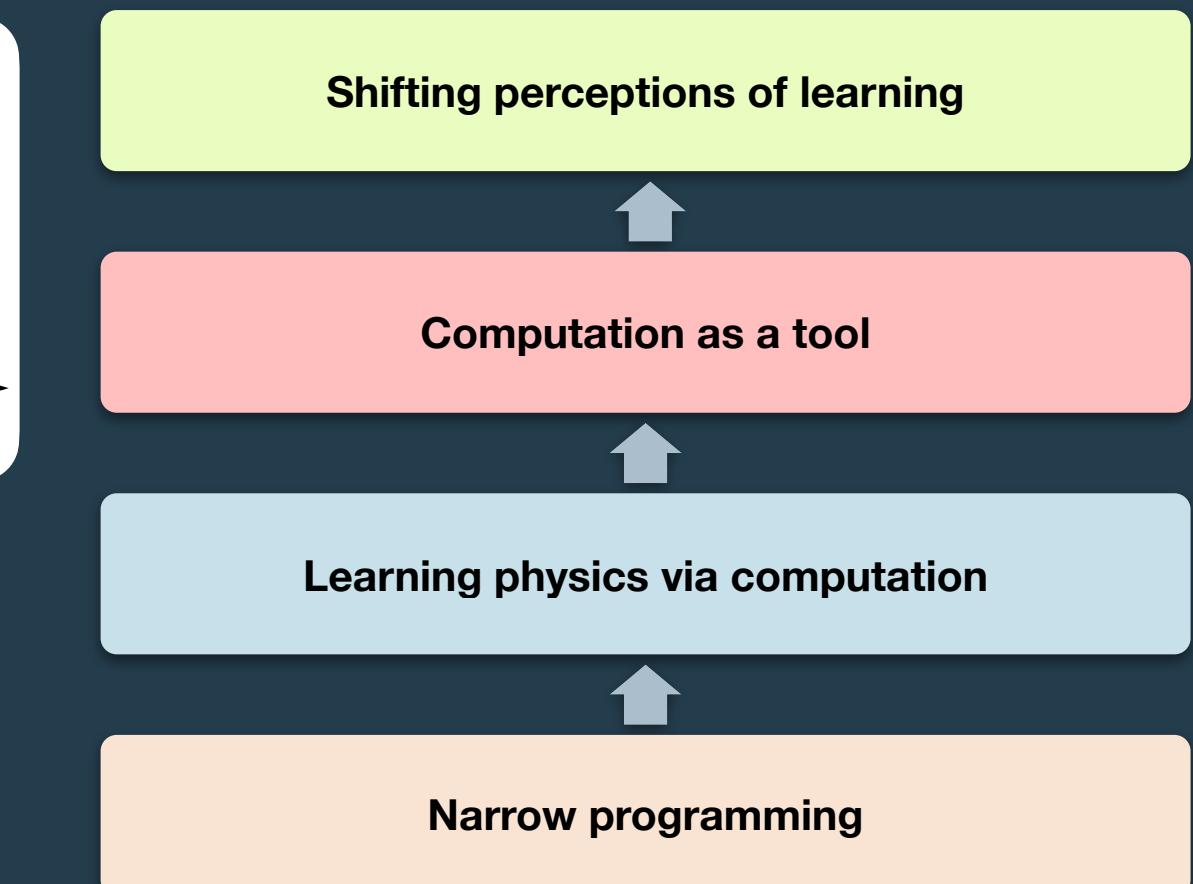
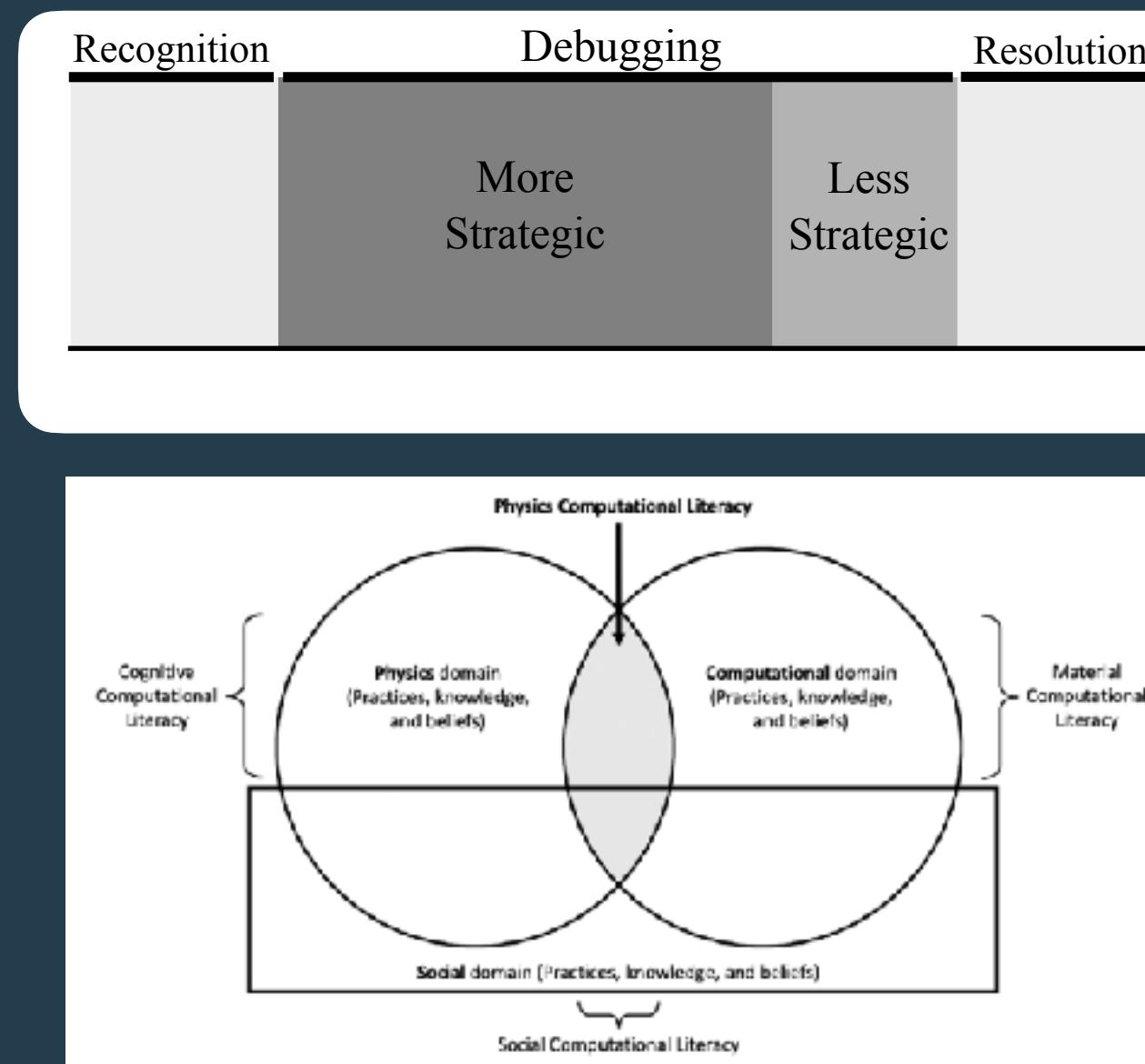
Funding Source: Michigan State University; Dr. William Martinez and Kelsey Funkhouser.

Funkhouser, Kelsey, et al. EJP 40.6 (2019): 065701.  
Henderson, Funkhouser, & Caballero 2019 PERC Proc.



# integrating computing in physics

## research



Obsniuk, Irving, Caballero, PERC 2015  
Pawlak, Irving, & Caballero, Phys. Rev. PER, 2020  
Odden, Lockwood, Caballero, Phys. Rev. PER, 2019

## faculty learning community

Screenshot of the PICUP website showing a physics exercise titled "A Rigid Three-bar Pendulum". The page includes details about the exercise, subject area (Mechanics), level (Beyond the First Year), available implementation (Python), learning objectives, and a list of requirements. The exercise is released under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 license.



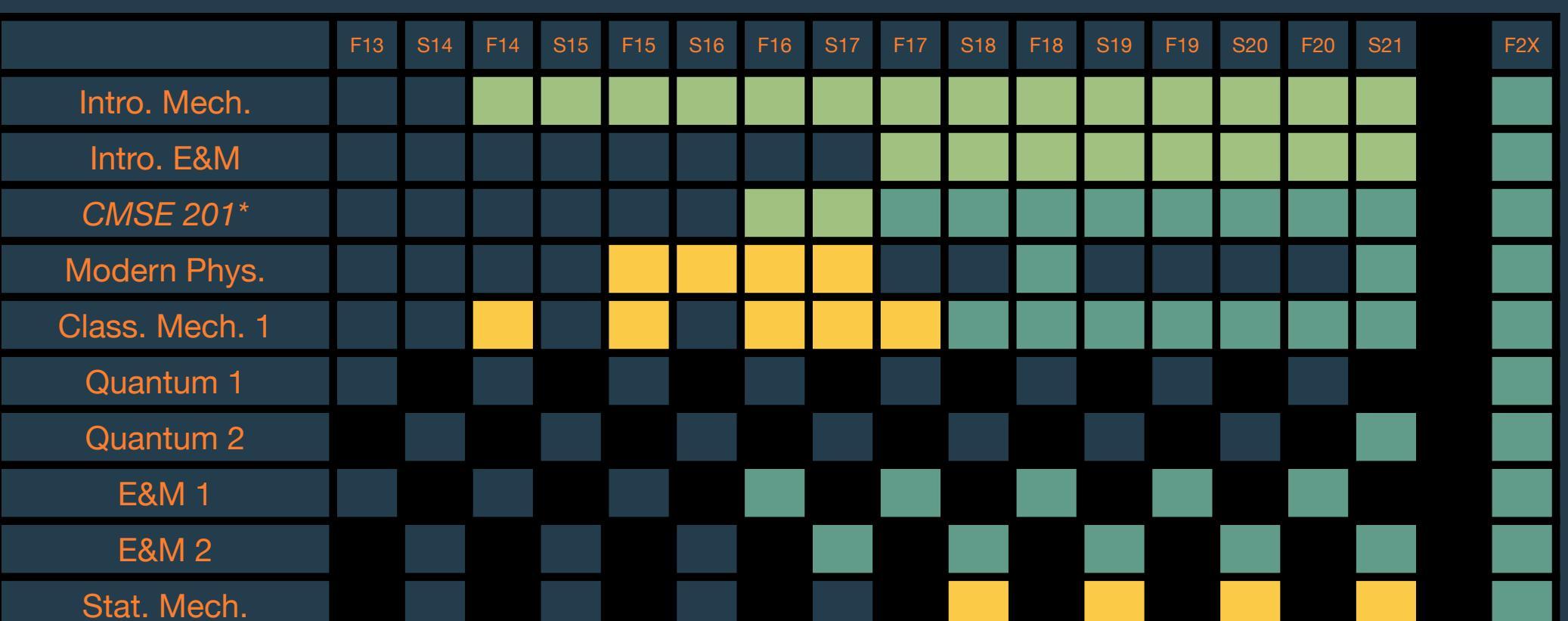
Caballero, et al. TPT 57.6 (2019): 397-399.  
gopicup.org

## community engagement

Screenshot of the EP3 Guide to Computational Skills website, showing the homepage and a section on Computational Skills.

## department-wide efforts

Caballero & Hjorth-Jensen, 2018



# supporting pre-college physics educators

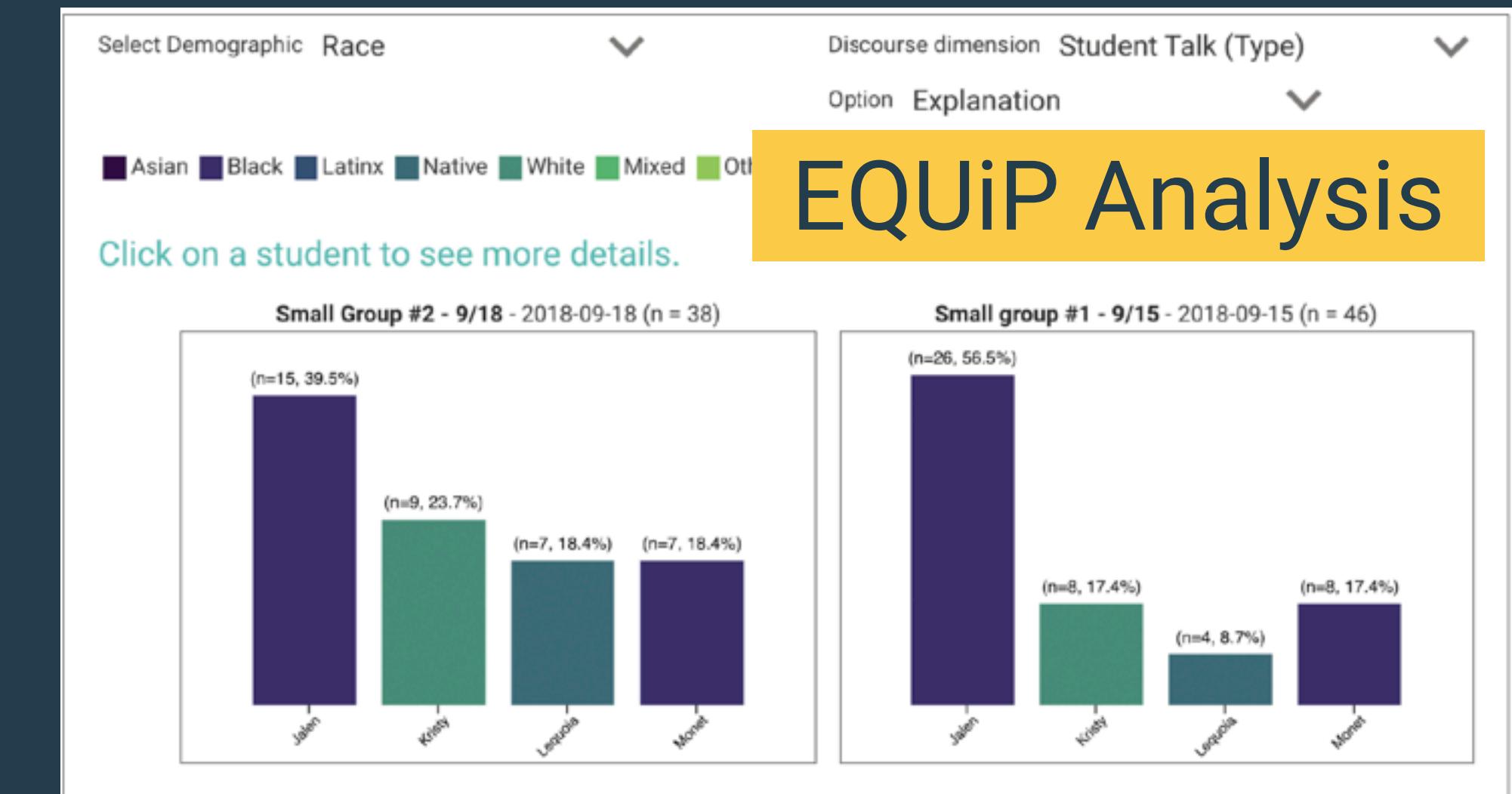


Michigan K-12 Standards  
**Science**  
November 2015

create a computational model to calculate...

use mathematical and/or computational representations to support explanations of factors...

use mathematical or computational representations to predict the motion...



### Marshmallow Launch

Activity Information

Learning Goals

- Create and modify a computational model to describe a given system
- Use Newton's second law to relate the acceleration of a marshmallow with the forces acting on it ([HS-PS2-1](#))

<https://www.msuperl.org/wp/icsam/>  
Weller, et al. Phys Rev PER 18.2 (2022): 020106.

teacher developed computing activities

Willison, et al. 2022 PERC Proc.  
Stroupe, David, et al. ICLS 2022.  
Hamerski, Patti C., et al. Phys Rev PER 18.2 (2022): 020109.



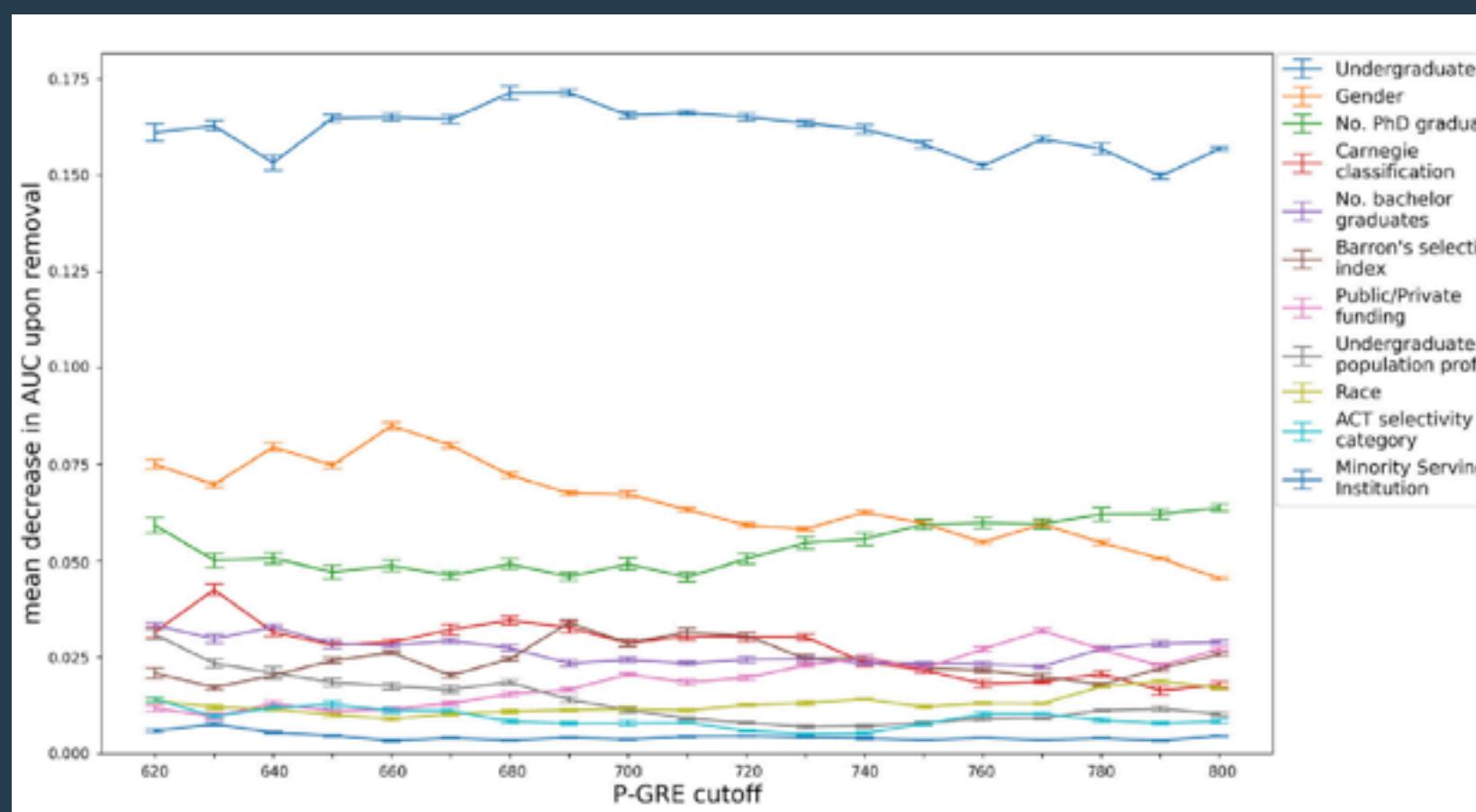
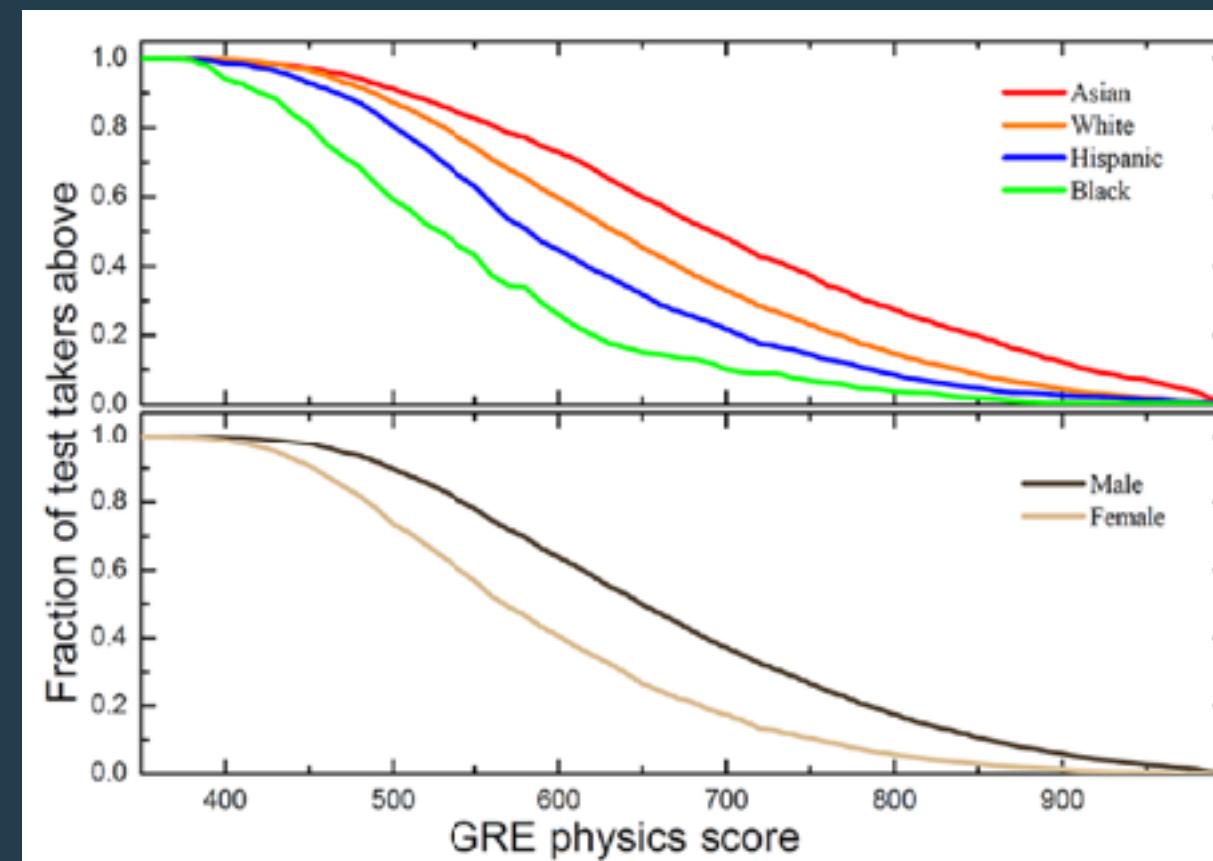
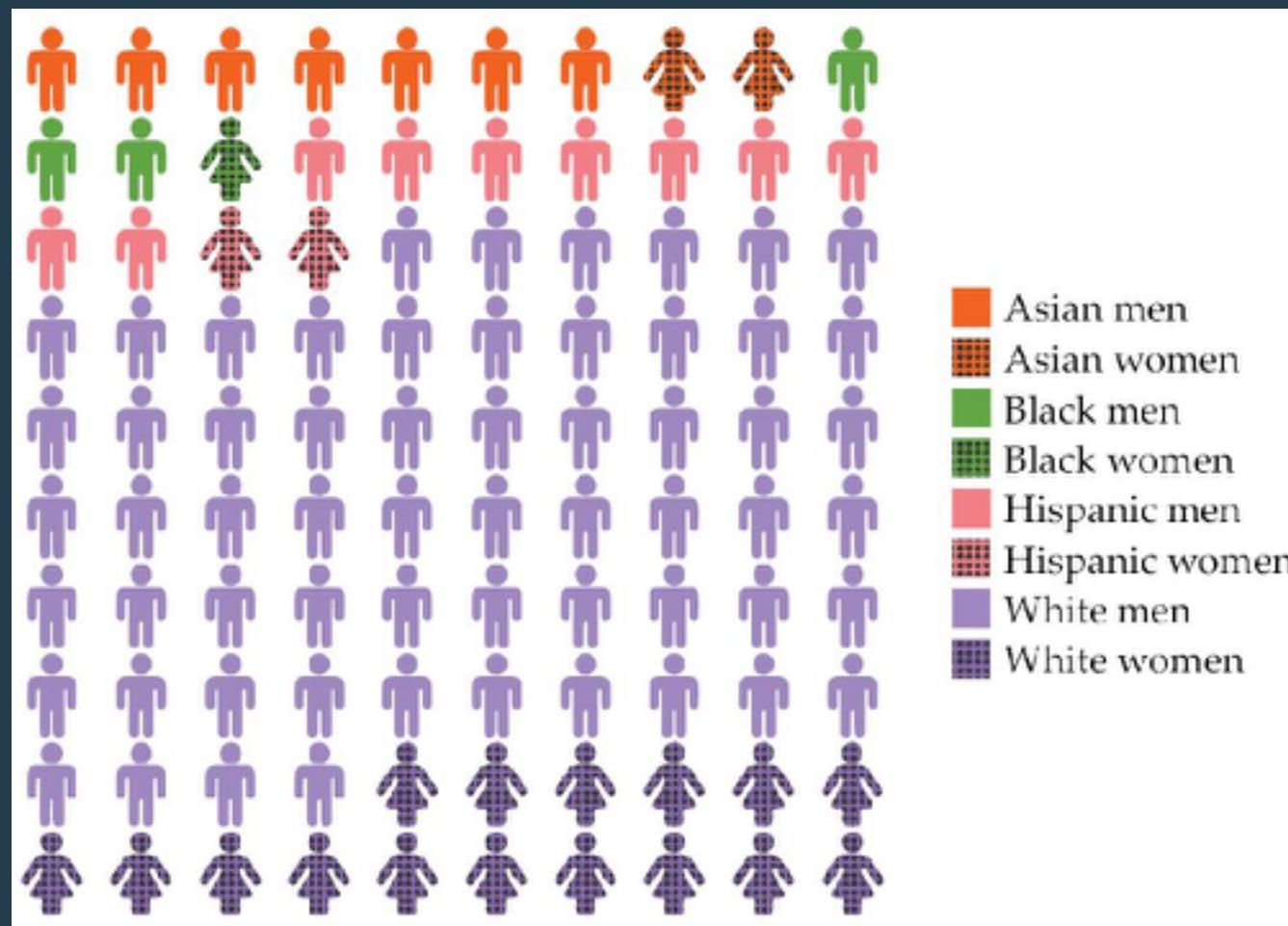
equip.ninja  
Christensen, et. al. TPT 60.6 (2022): 414-418.

# diversifying graduate physics programs

MICHIGAN STATE  
UNIVERSITY



potential physics phd applicants



disaggregated  
gre distribution

gre cutoffs  
limit diversity

using holistic admissions rubric

	Low	Medium	High
Physics coursework	✗	✓	
Math coursework	✗	✓	
All other coursework		✓✗	
Academic honors	✗	✓	
Variety/duration of research		✓✗	
Quality of work	✗	✓	
Technical skills	✗	✓	
Research dispositions	✗	✓	
Achievement orientation	✗	✓	
Conscientiousness	✗	✓	
Initiative	✗	✓	
Perseverance	✗	✓	
Alignment of research	✗	✓	
Alignment with faculty	✗	✓	
Community contributions	✗	✓	
Diversity contributions	✗	✓	
General GRE scores	✓✗	✓	✗
Physics GRE score	✗	✓	

✓ Admitted    ✗ Nonadmitted

Young, Verboncoeur, Lam, and Caballero. *Phys Rev PER* 19.1 (2023): 010134.  
Young, Tollefson, Zegers, and Caballero. *Phys Rev PER* 18.2 (2022): 020140.  
Young and Caballero. *Phys Rev PER* 17.1 (2021): 010144.  
Mikkelsen, Young, and Caballero. *Phys Rev PER* 17.1 (2021): 010109.

**more folks learn  
science better**

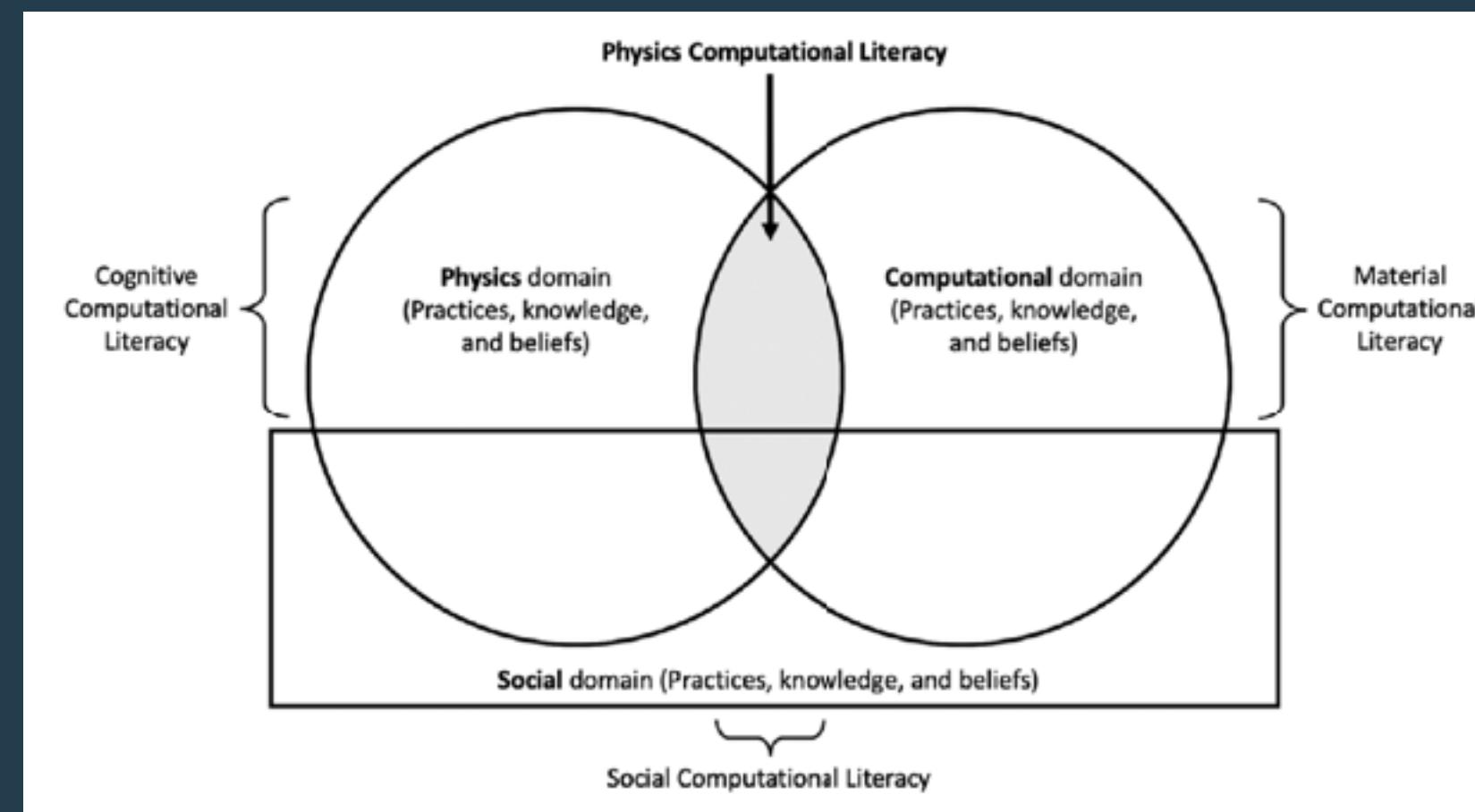
**greater diversity  
across all of  
science**

A science that is more  
representative of and  
responsive to society

A society that deeply  
values and strongly  
supports science



# computing is increasingly important to learn and to shape developing computational literacy

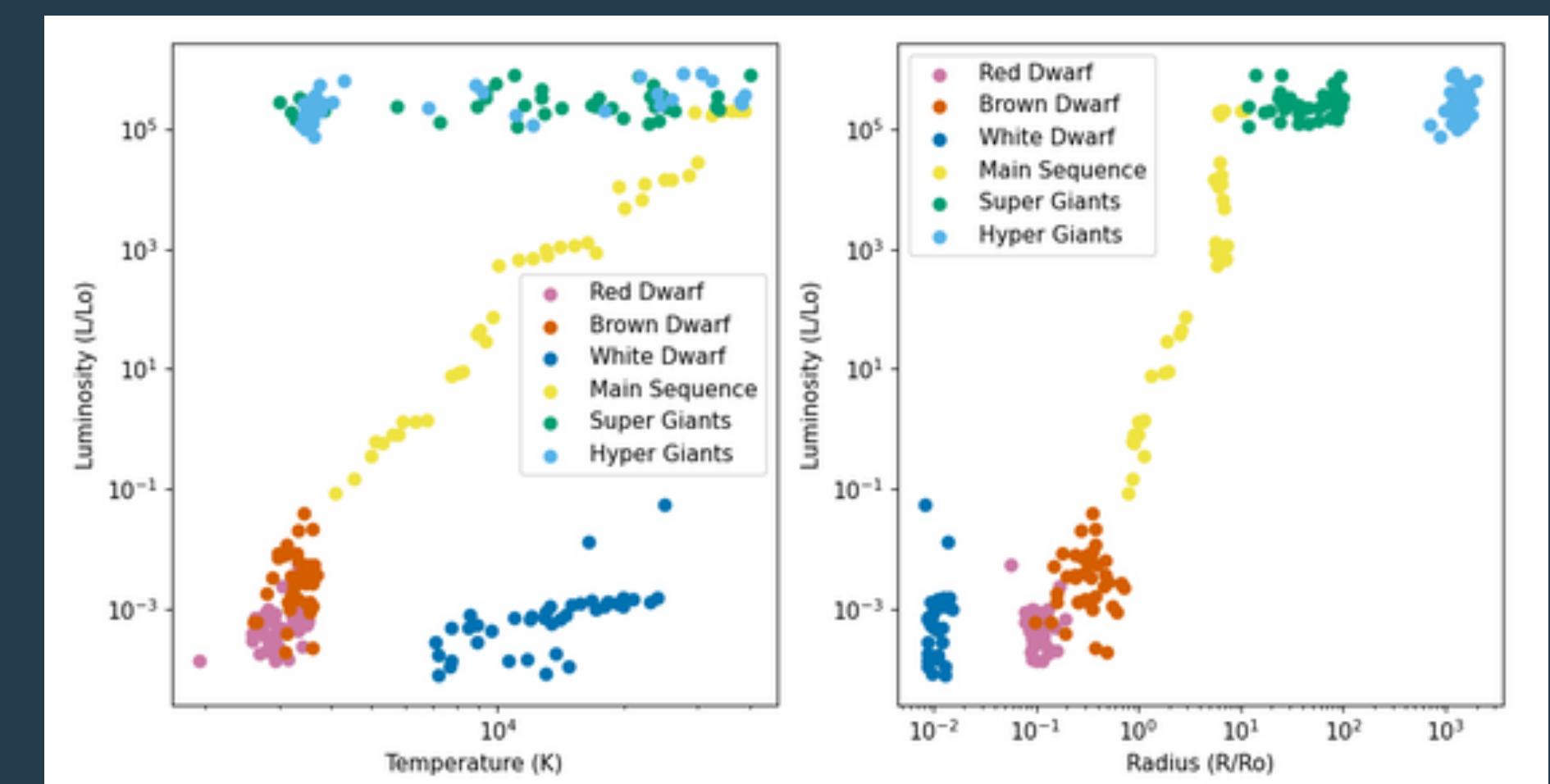
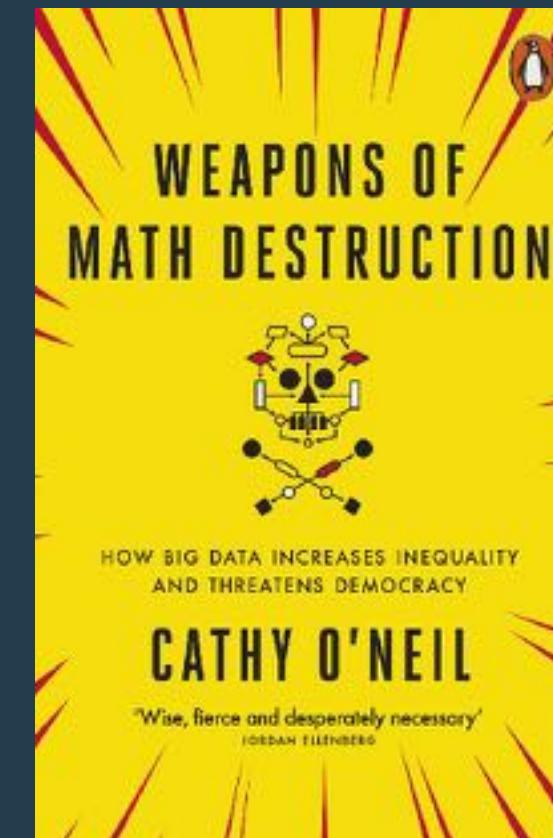
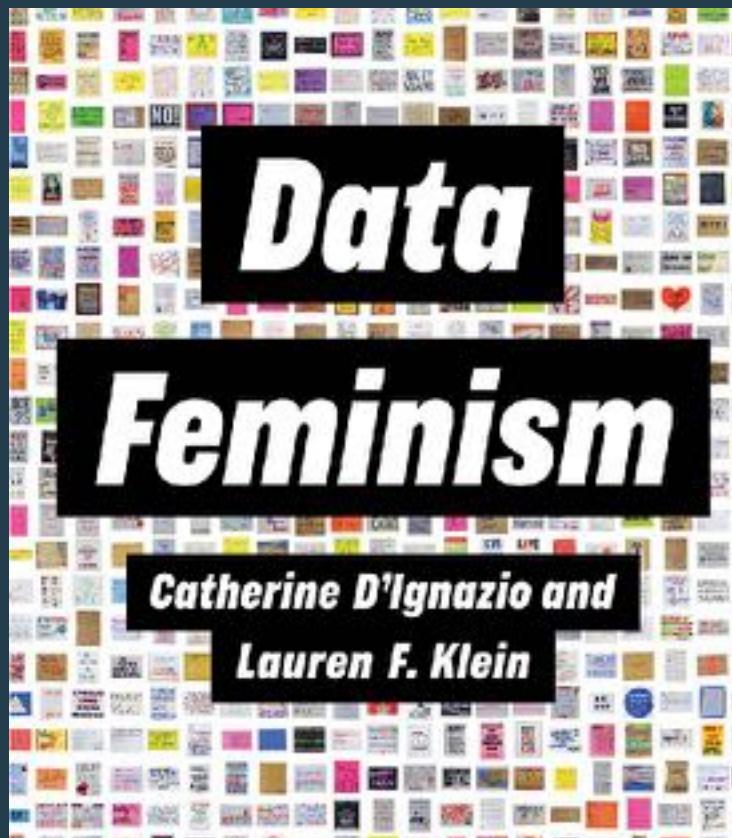
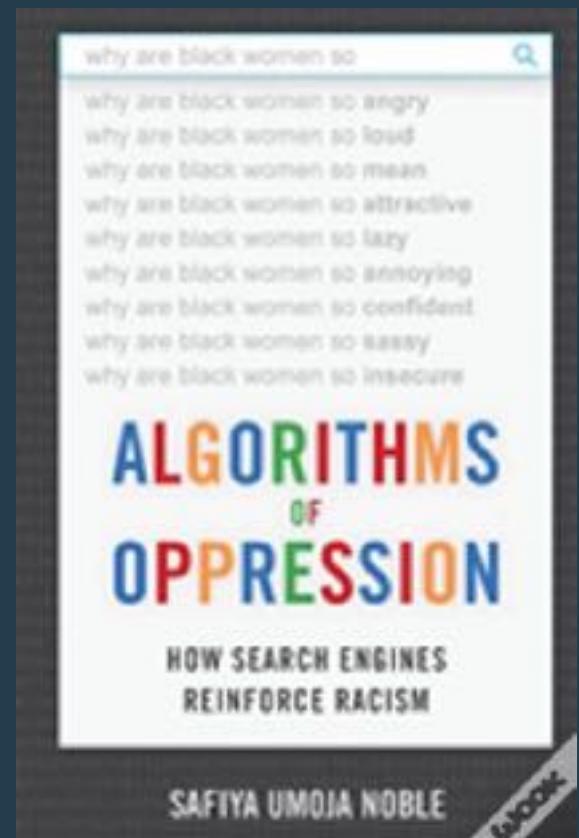


Odden, Lockwood, Caballero, Phys. Rev. PER, 2019

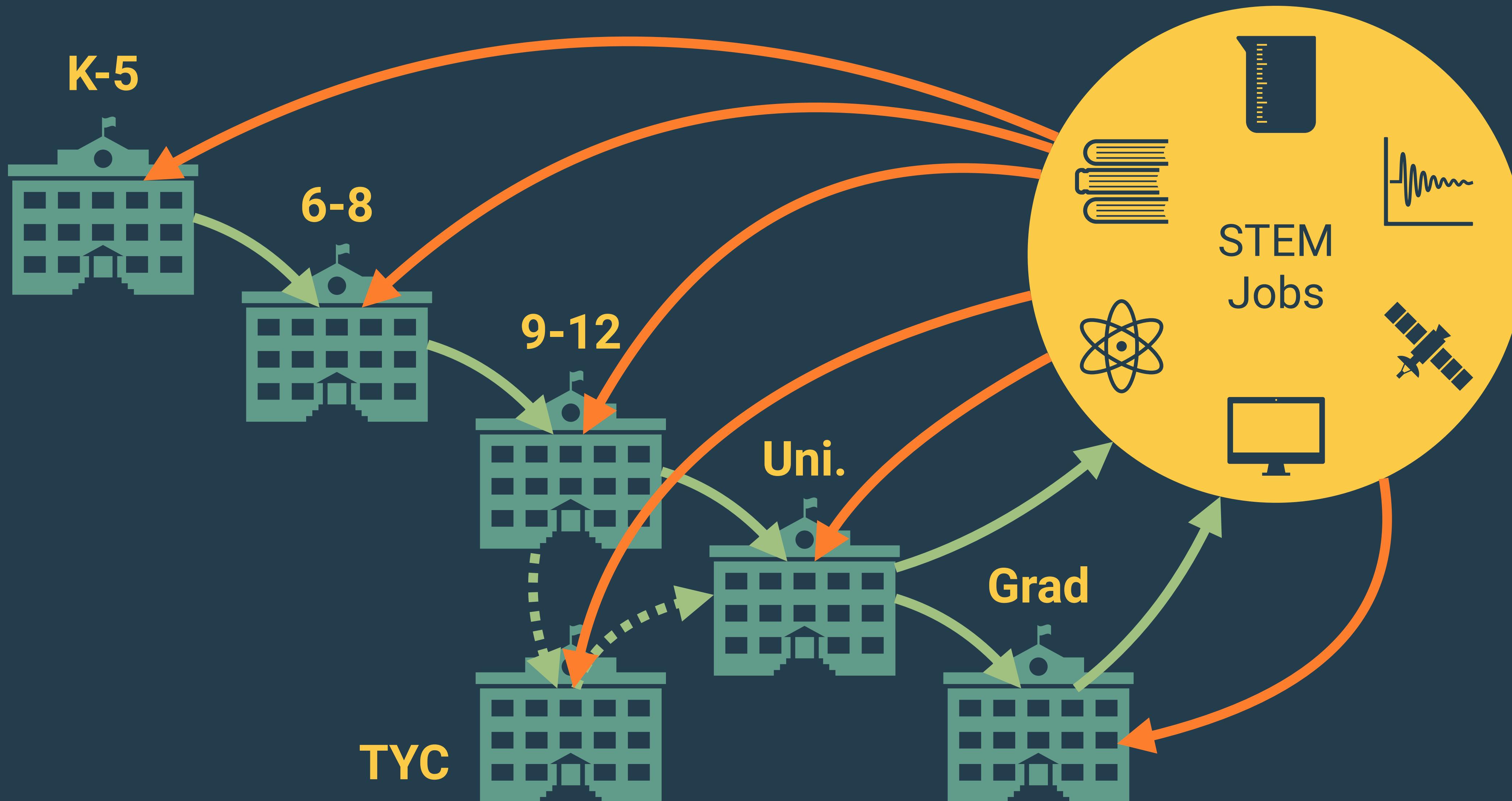
cmse 201/202  
modeling,  
machine learning,  
& data science



computing for justice?



# our educational systems are interconnected not isolated



# new technologies can enhance and disenfranchise

⊕ GPT-4



write a problem for me that has three degrees of freedom, but one constraint that can be solved with Lagrangian mechanics. Don't show me how to solve it. Just show me a problem that can be solved using that approach.



Certainly! Here's a problem that involves three degrees of freedom with one constraint, suitable for analysis using Lagrangian mechanics:



## Pendulum with a Sliding Bead:

Consider a pendulum of length  $L$  which is free to swing in a vertical plane. This pendulum is composed of a lightweight, inextensible rod with a frictionless hinge at its upper end, allowing it to swing freely. Attached to this rod is a small bead of mass  $m$  that can slide along the rod without any friction. The bead is not fixed and is influenced by gravity, so it can slide up and down the rod as the pendulum swings.

Given:

# Thank you!

