

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

michigan state university
13 sept 2023

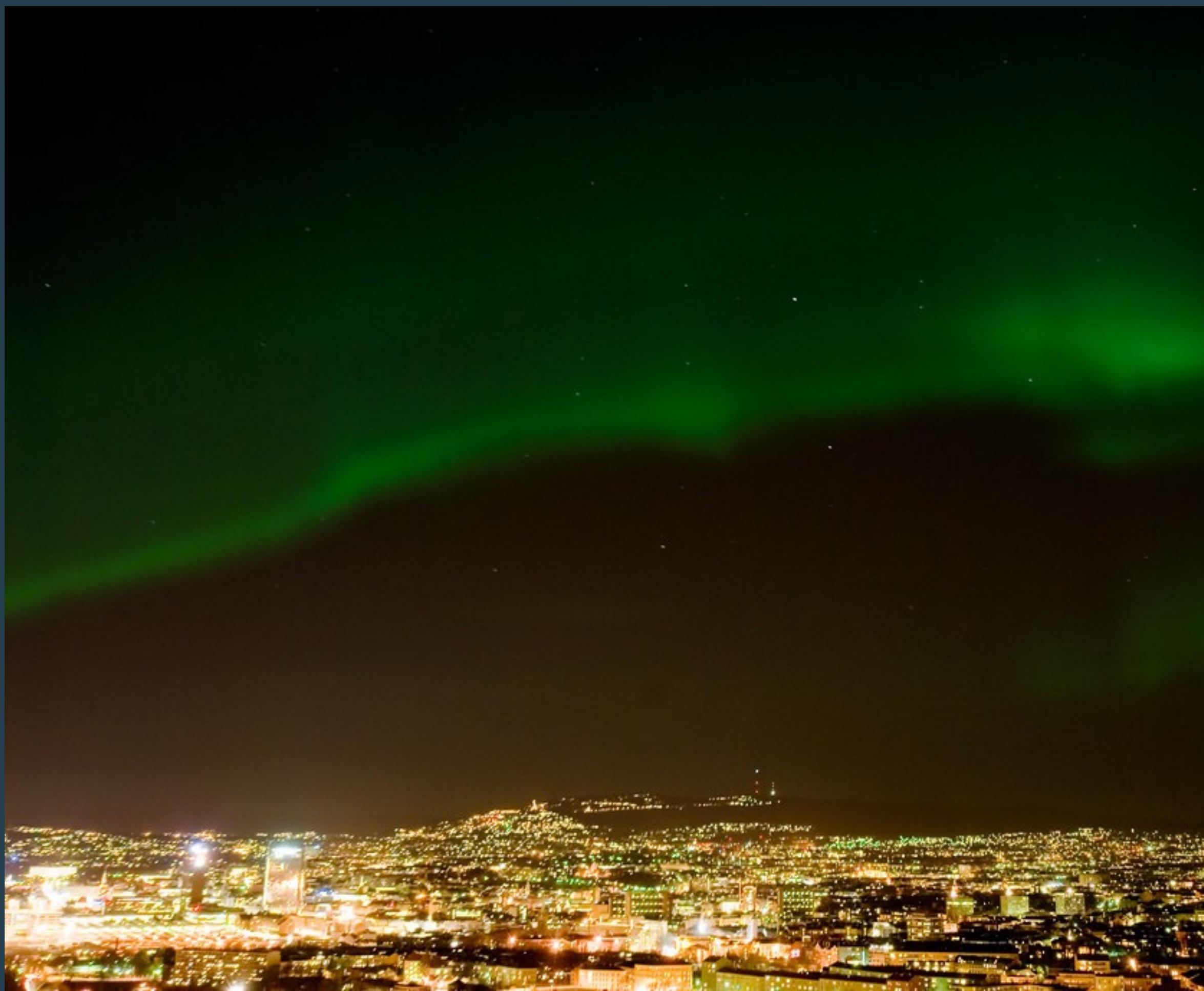
danny caballero (he/him)

department of physics and astronomy

department of computational mathematics, science, and engineering

create for stem institute





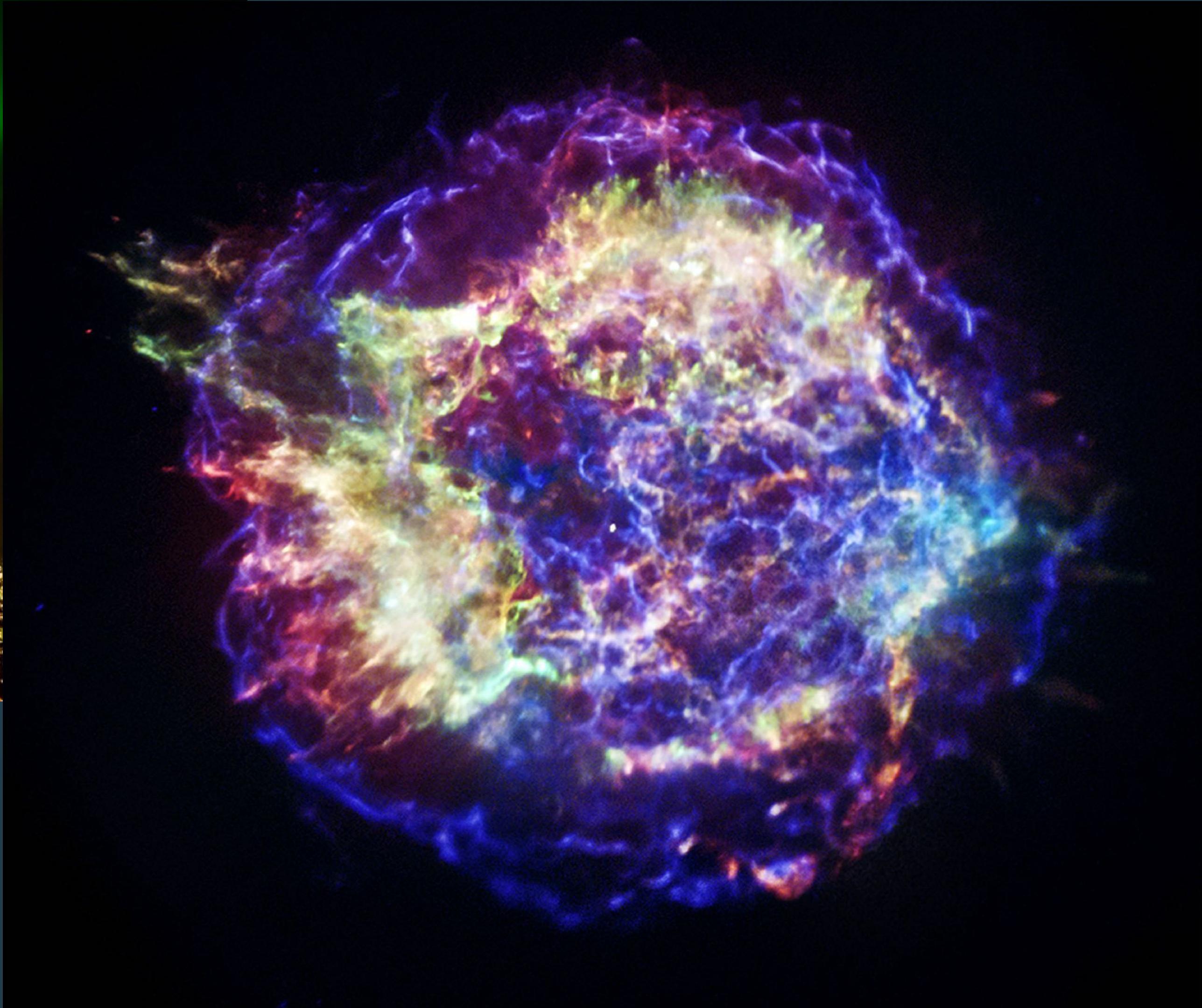
aurora borealis over oslo

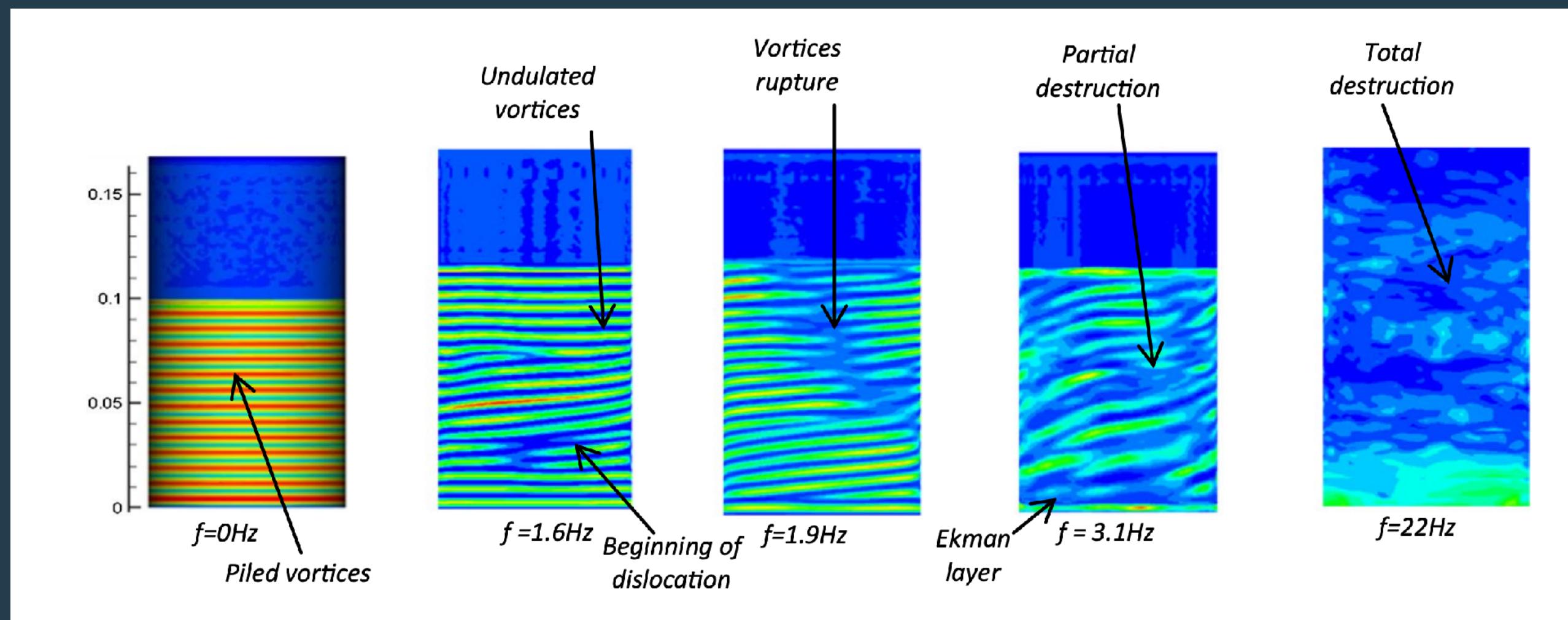
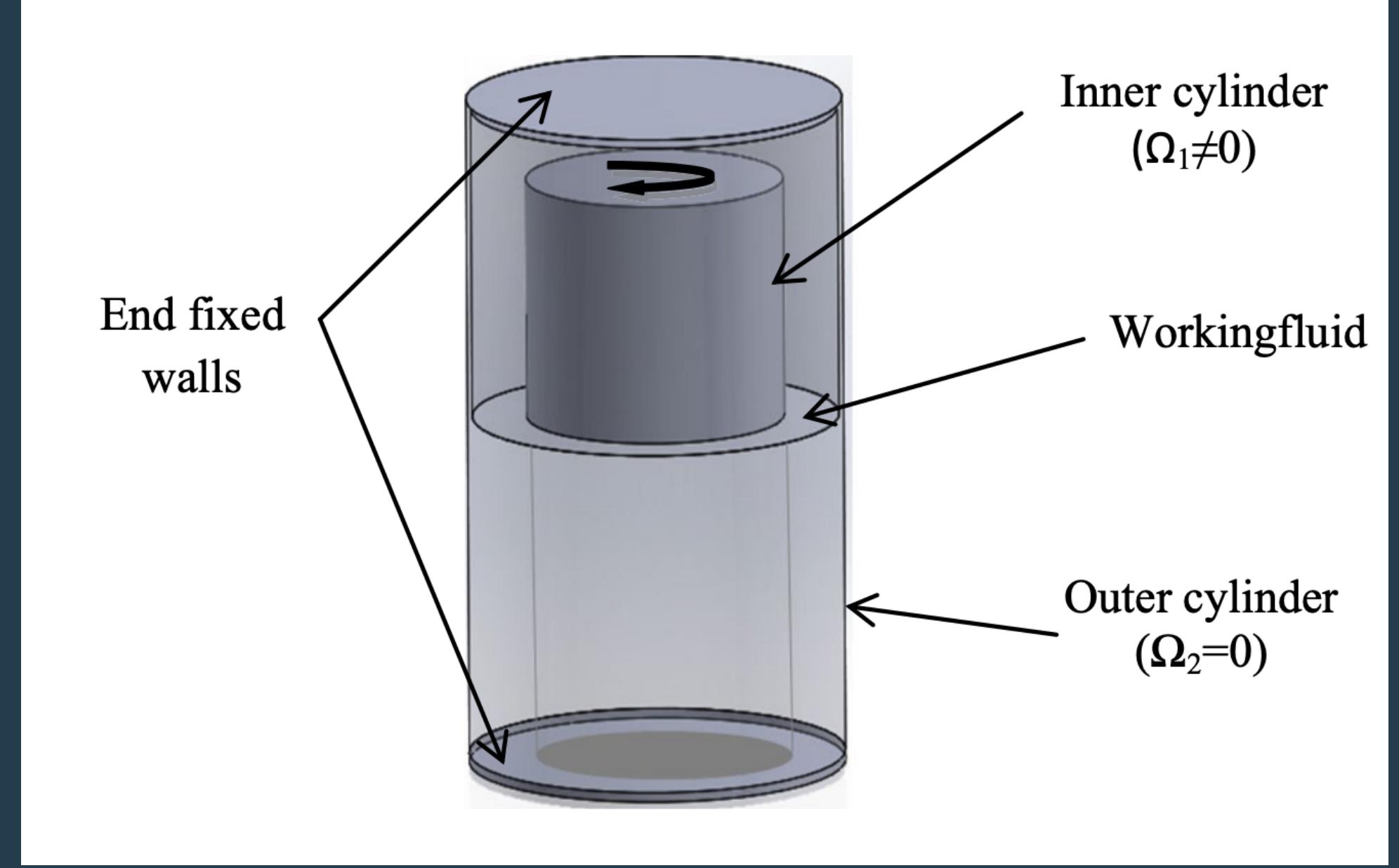
<https://www.flickr.com/photos/65218245@N00/326627830>

science can explain
natural phenomena

supernova remnant - cassiopeia a

https://www.nasa.gov/mission_pages/chandra/multimedia/exploring-cassiopeiaA.html





taylor-couette cylinder & transition to turbulence

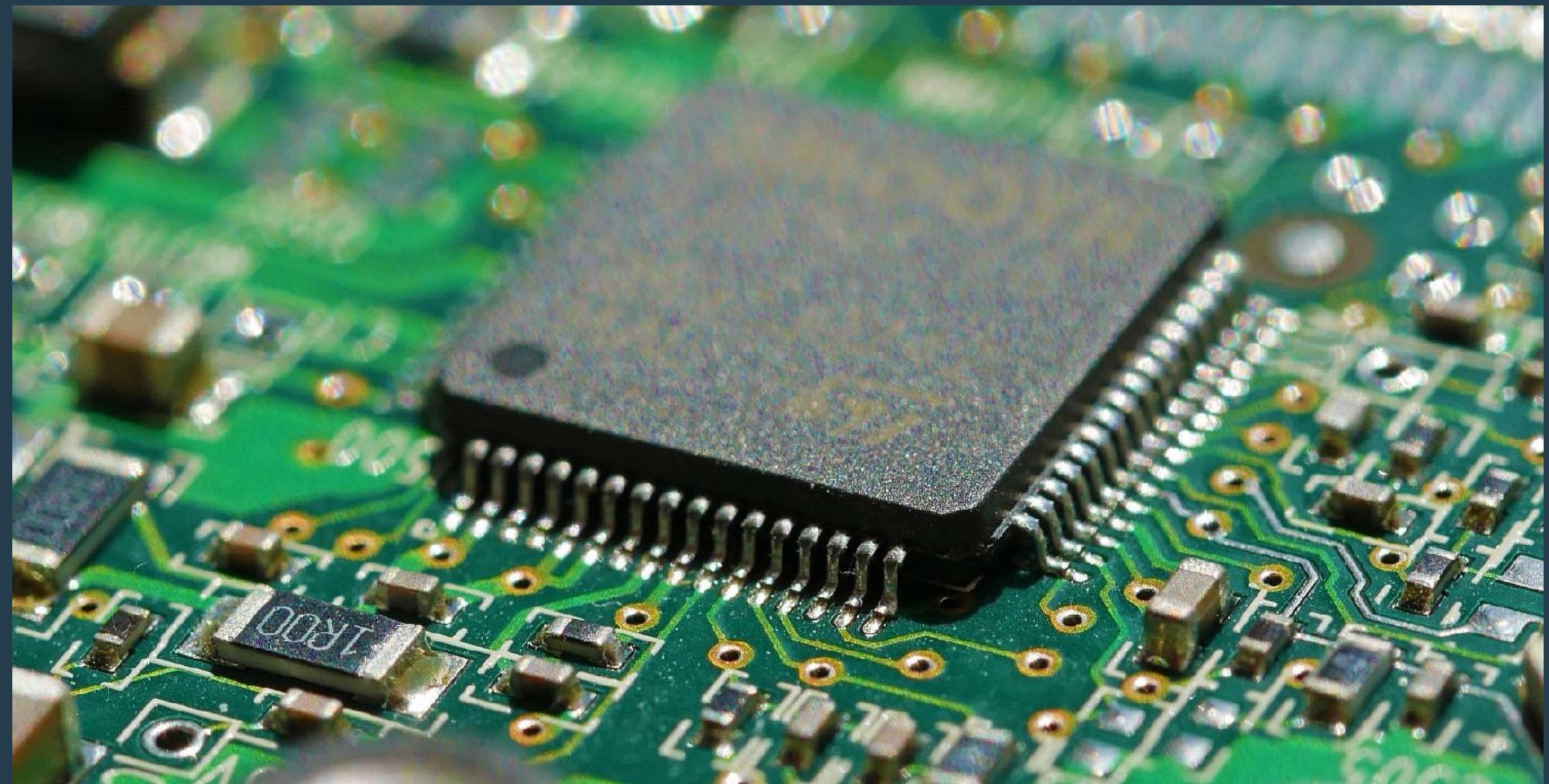
Abdelali, A., et al. *Journal of the Brazilian Society of Mechanical Sciences and Engineering* 41.6 (2019): 259.

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

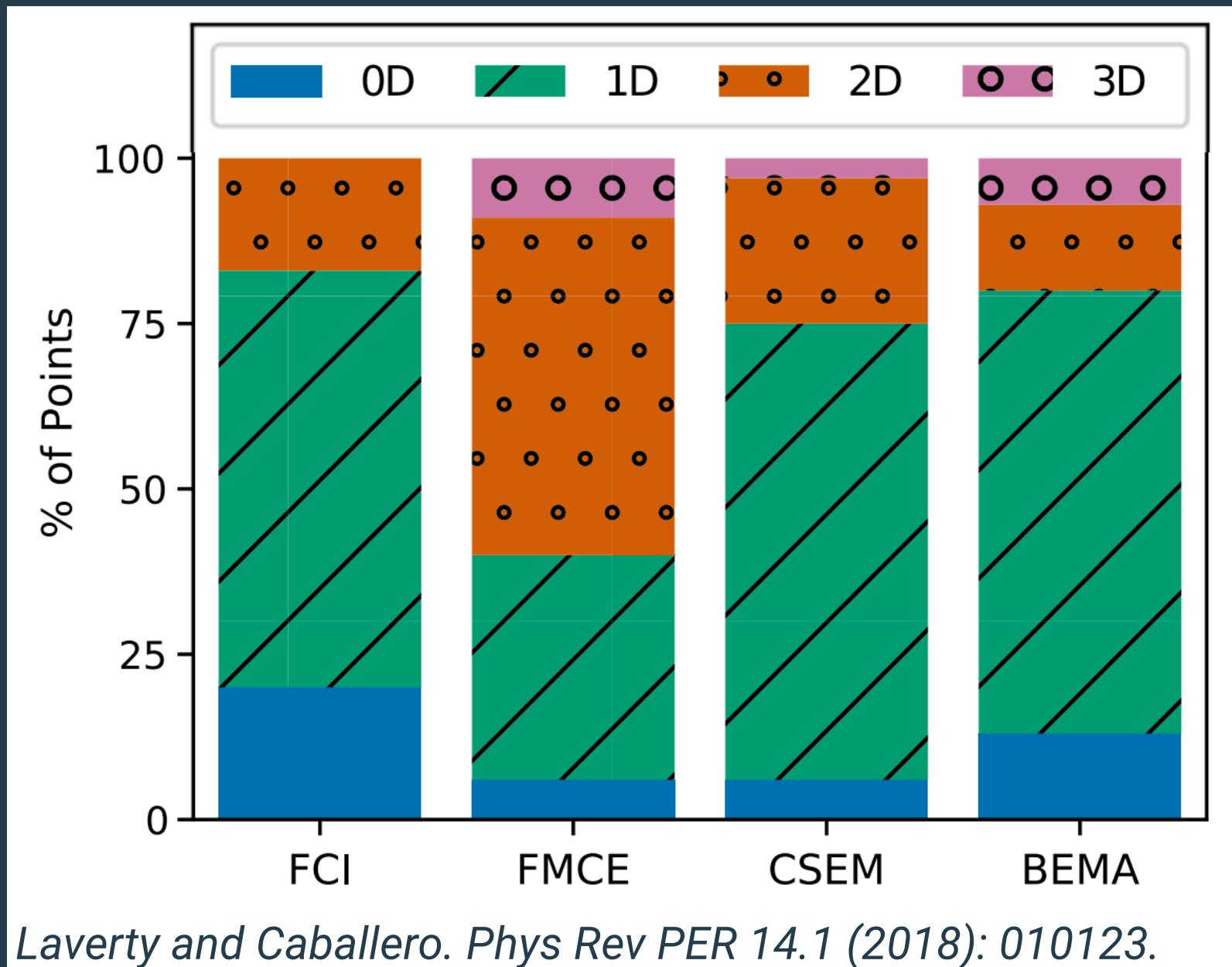
we discover, design, and develop the conditions
and environments in which all folks who are
learning science can thrive

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	Lecture
SP		None	None	None	None	None	None
CI		—	—	—	—	—	—
CC		—	—	—	—	—	—

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

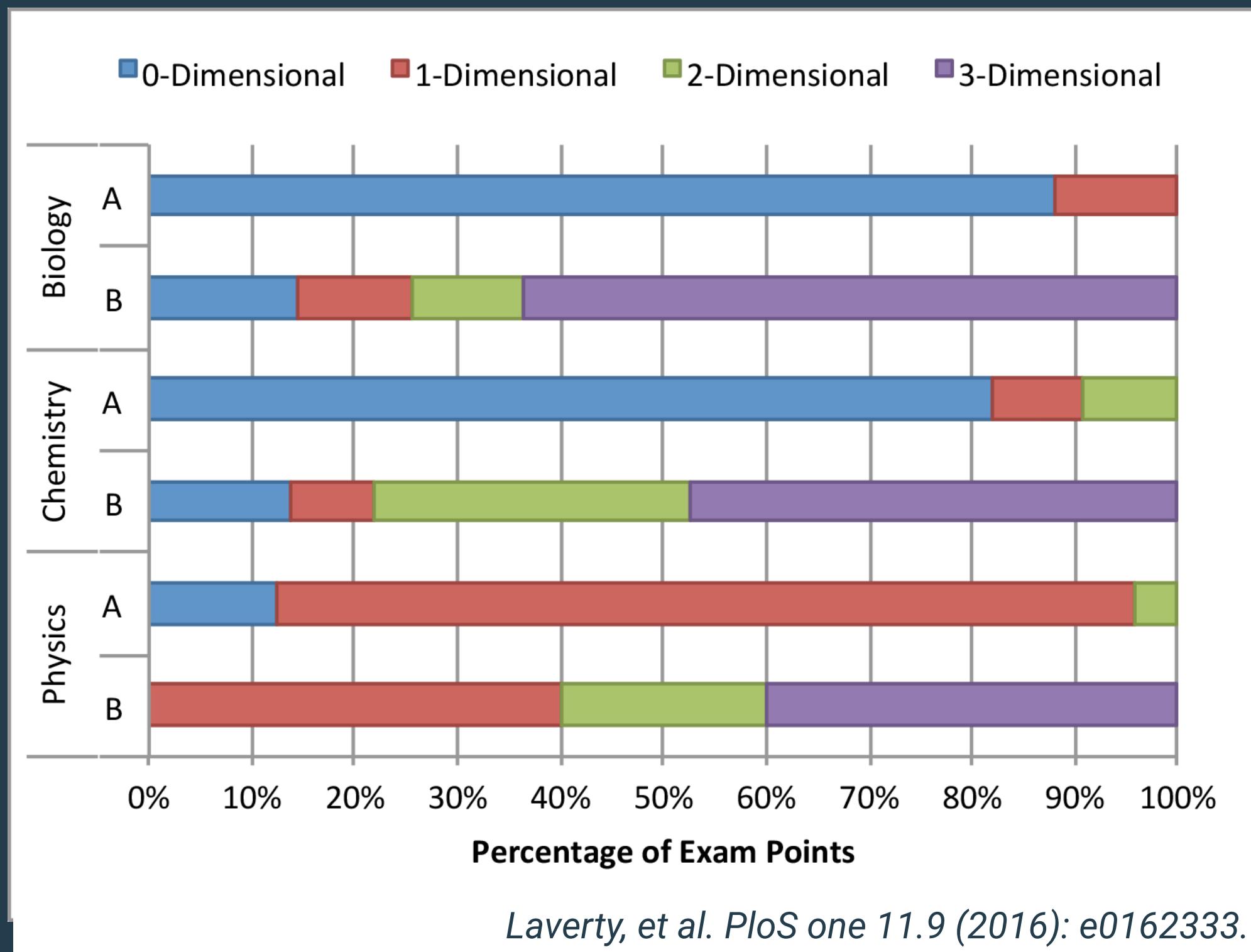


Laverty and Caballero. Phys Rev PER 14.1 (2018): 010123.

active learning is
not necessarily
3d learning



three-dimensional learning
assessment protocol (3DLAP)



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

developing community-based courses

projects and practices in physics

The screenshot shows a web-based simulation titled "Project 3: Geosynchronous Orbit: Part A". It features a 3D representation of Earth and a satellite in orbit, with arrows indicating velocity and gravitational forces. Below the simulation is a code snippet for a Python script named "gaosync.py".

```
# 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 = (7.29e-5) * deltat # IGNORE THIS LINE
    Earth.rotate(angle=theta, axis=vector(0,0,1), origin=vector(0,0,0)) # IGNORE THIS
    Satellite.pos = Satellite.pos + pSatellite/mSatellite*deltat
    SatelliteMotionMap.update(t, pSatellite/mSatellite)
    t = t + deltat
```



group-based

Irving, Obsniuk, & Caballero, EJP (2017)

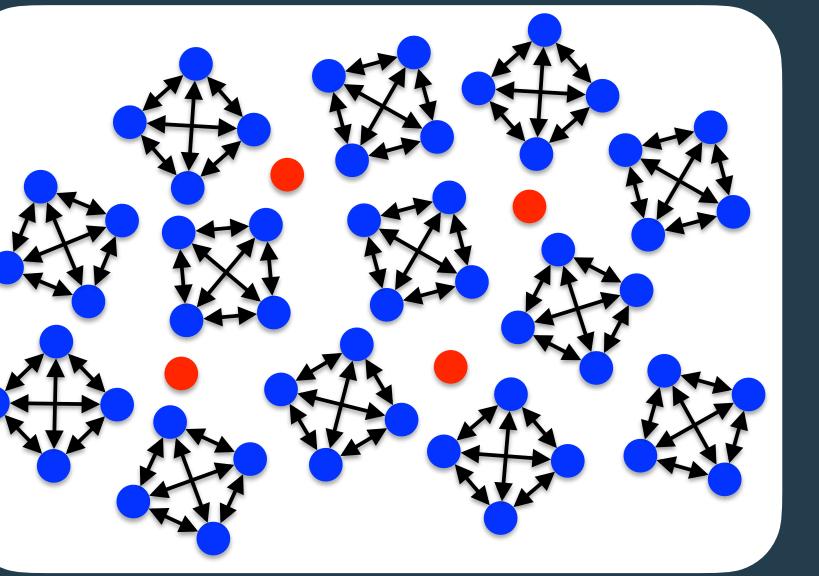
Pawlak, Irving, & Caballero, Phys. Rev. PER (2020)

Irving, McPadden, & Caballero Phys. Rev. PER (2020)

MICHIGAN STATE
UNIVERSITY



LAs



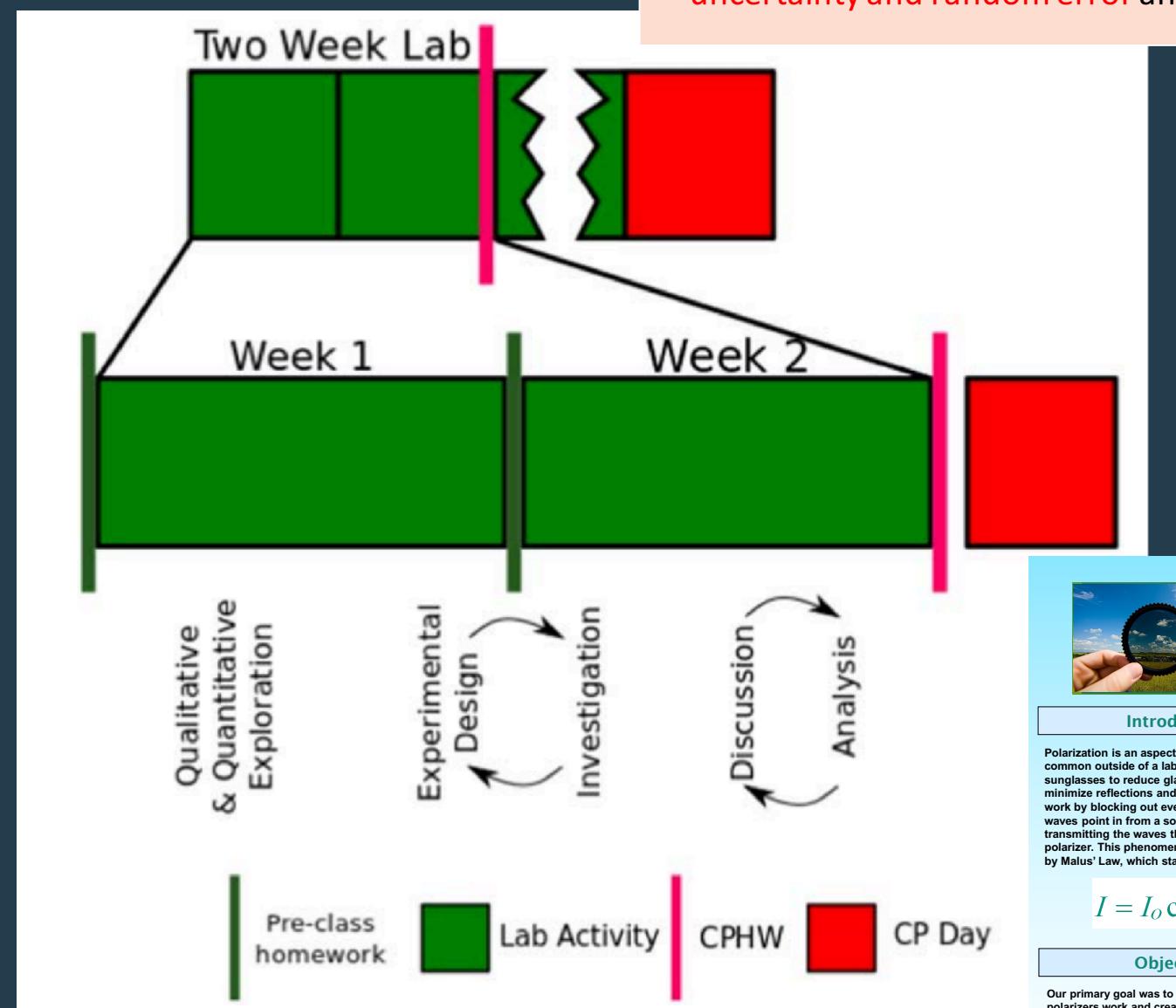
computing



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

This screenshot shows a lab page for a polarization experiment. It includes sections for Introduction, Methods, and Conclusion. The Methods section contains a graph showing light intensity versus angle of a second polarizer. The Conclusion section discusses the inverse relationship between intensity and angle.

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

Introduction

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

$$I = I_0 \cos^2\theta$$

Methods

When initially making observations about the polarizers, 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 was.

The model 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.

Conclusion

When light passes through two polarizers, we should have seen no light, but we still saw some because the polarizers aren't made perfectly. The primary errors 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.

Angle of Polarizer 2 (°)	Intensity (Relative Intensity)
0	100
10	80
20	65
30	55
40	48
50	42
60	37
70	32
80	28
90	25
100	22

Objectives

Our primary goal was to understand how polarizers work and create a model to account for all of the light passing through two polarizers and what the resulting intensity would be.

Materials

Light source, Polarizers, Detector, Ruler, Protractor, Notebook, Pen.

Procedure

1. Set up the light source and detector. 2. Place the first polarizer in front of the light source and the second polarizer in front of the detector. 3. Adjust the angle of the second polarizer and record the resulting intensity. 4. Repeat steps 3-4 for various angles of the second polarizer.

Data

Angle of Polarizer 2 (°)

Intensity (Relative Intensity)

Analysis

The data shows a clear inverse relationship between the angle of the second polarizer and the resulting intensity. As the angle increases, the intensity decreases. This is consistent with Malus' Law.

Conclusion

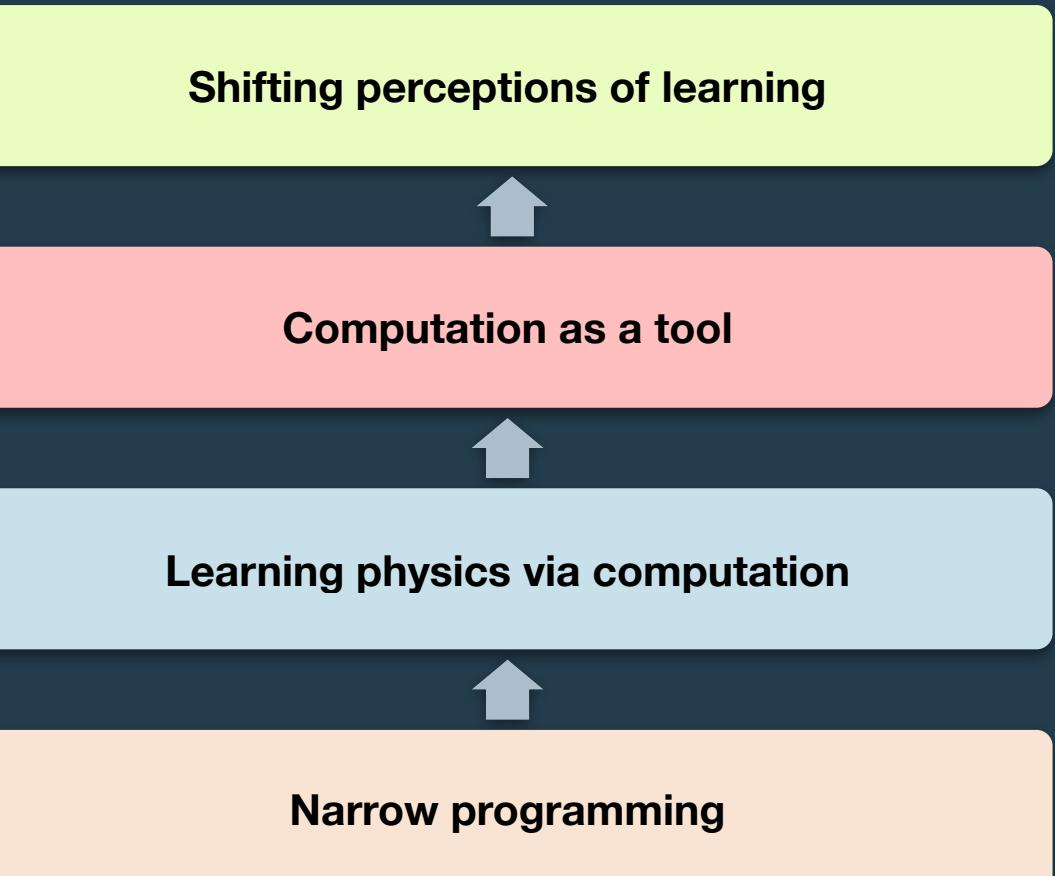
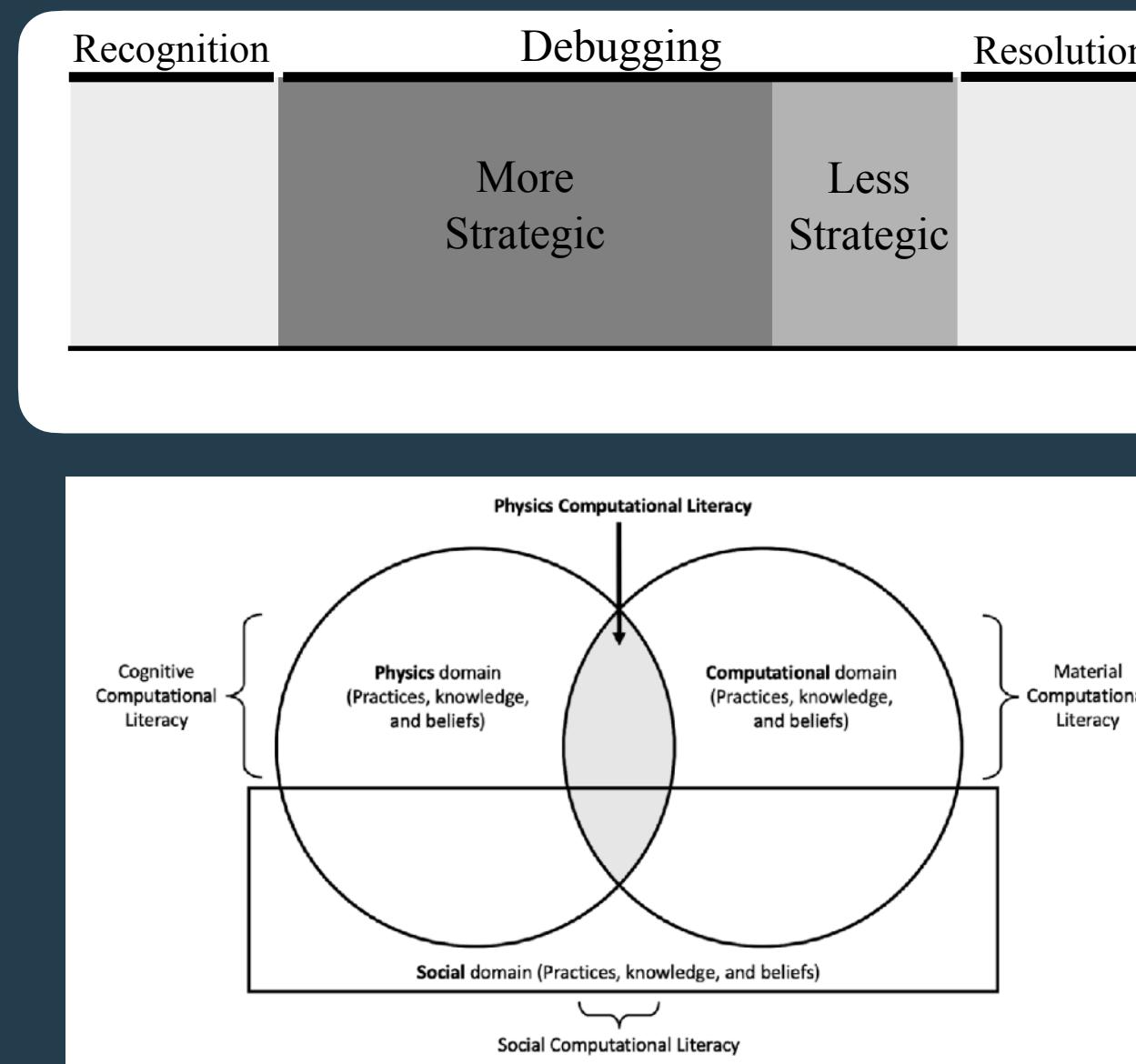
Based on the data, we can conclude that the intensity of light passing through two polarizers is inversely proportional to the angle between them. This is consistent with Malus' Law.

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

HHMI
HOWARD HUGHES MEDICAL INSTITUTE

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

The screenshot shows the PICUP website interface. At the top is a navigation bar with links for Home, Exercise Sets, Faculty Commons, Resources, Community, Events, and About PICUP. The 'Exercise Sets' tab is active, showing a list item for 'A Rigid Three-bar Pendulum' developed by E. Behringer on July 31, 2016. The page details the exercise, subject area (Mechanics), level (Beyond the First Year), available implementation (Python), and learning objectives. It also includes a preview image of a contour plot and a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 license logo.



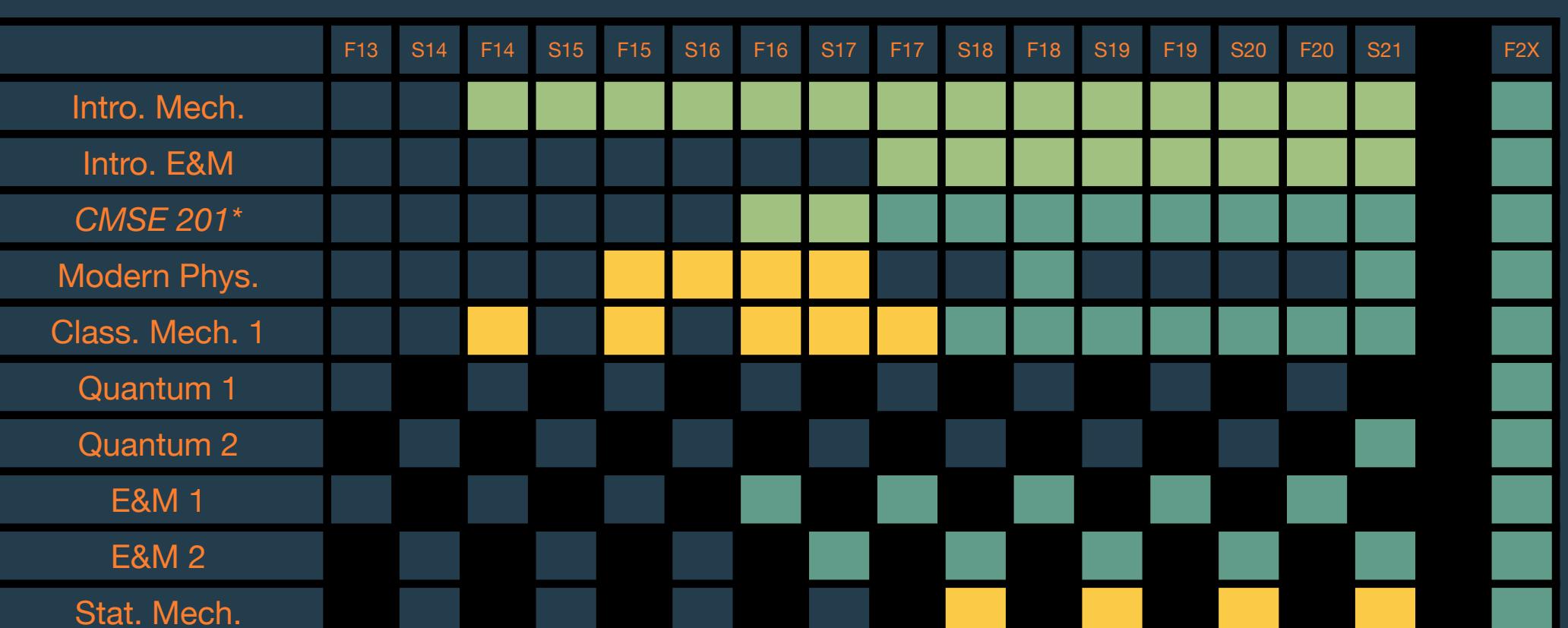
Caballero, et al. TPT 57.6 (2019): 397-399.
gopicup.org

community engagement

The screenshot shows the EP3 Guide to Computational Skills website. The header includes links for FAQ, Events, Contact, and About. Below is a navigation bar with links for Guide Overview, Get Started, Map Your Program's Goals, Help & Community, and Search. The main content area is titled 'Guide to Computational Skills' and includes sections for Computational Skills, Version 1, January 29, 2021, Contributors and Reviewers, Description, Benefits, Effective Practices, Programmatic Assessments, Resources, Evidence, and Glossary.

department-wide efforts

Caballero & Hjorth-Jensen, 2018



supporting pre-college physics educators



Michigan K-12 Standards
Science
November 2015

MICHIGAN Department of Education

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

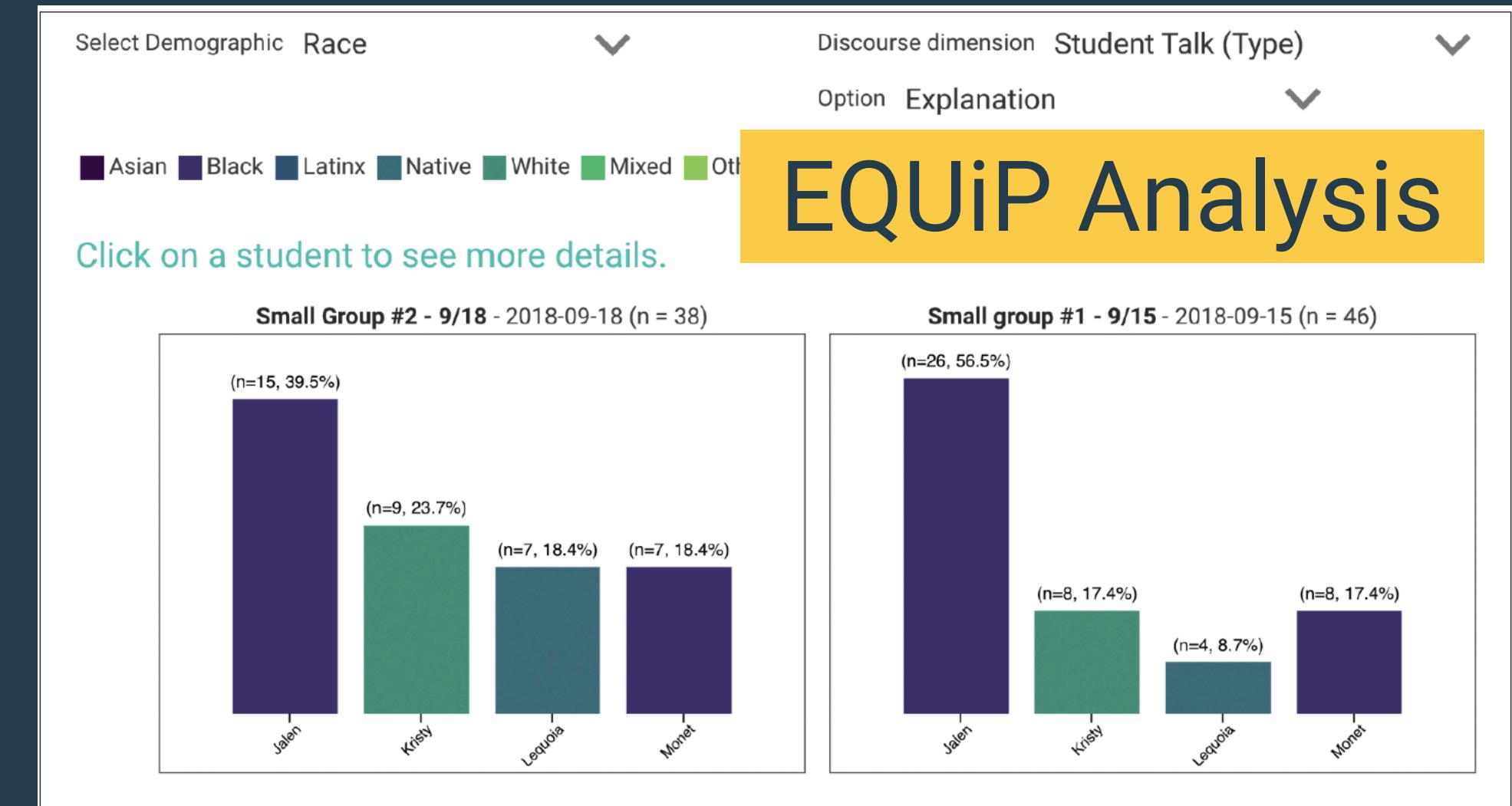
Learning Goals

- 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.

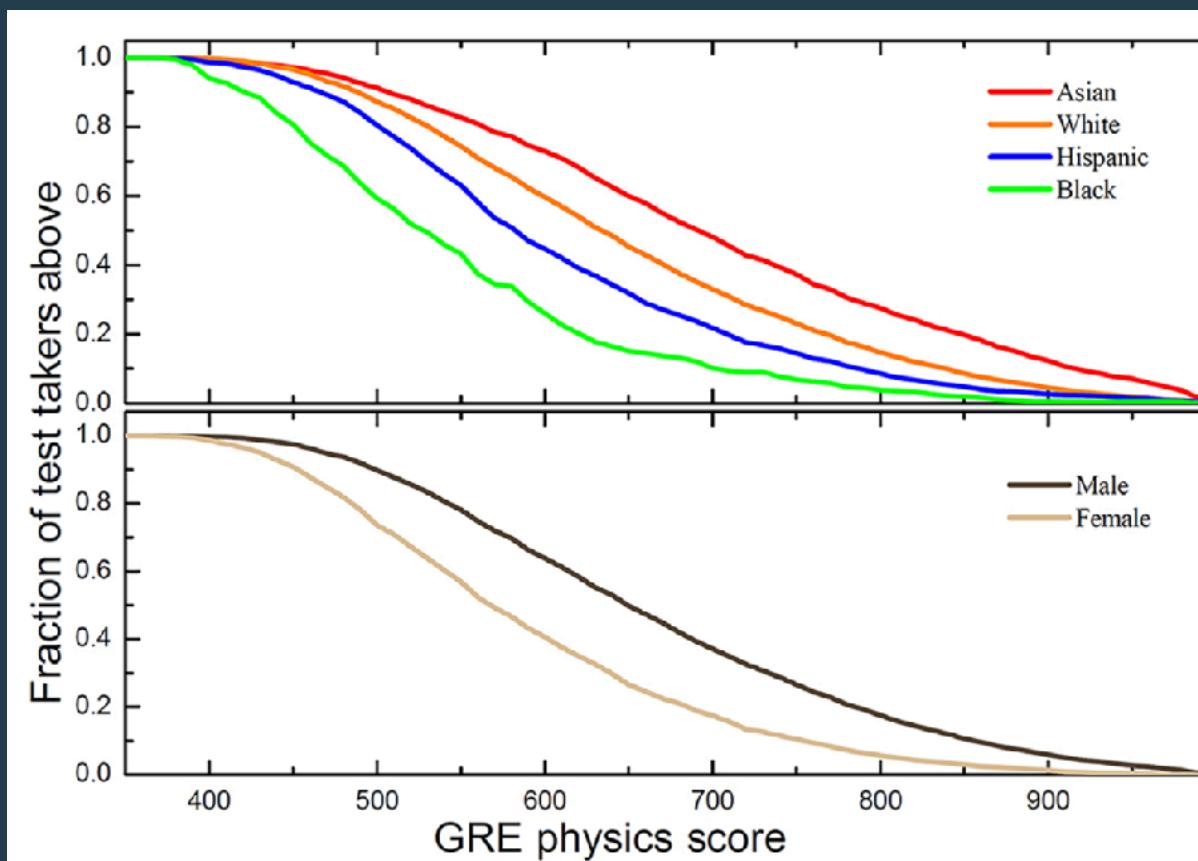
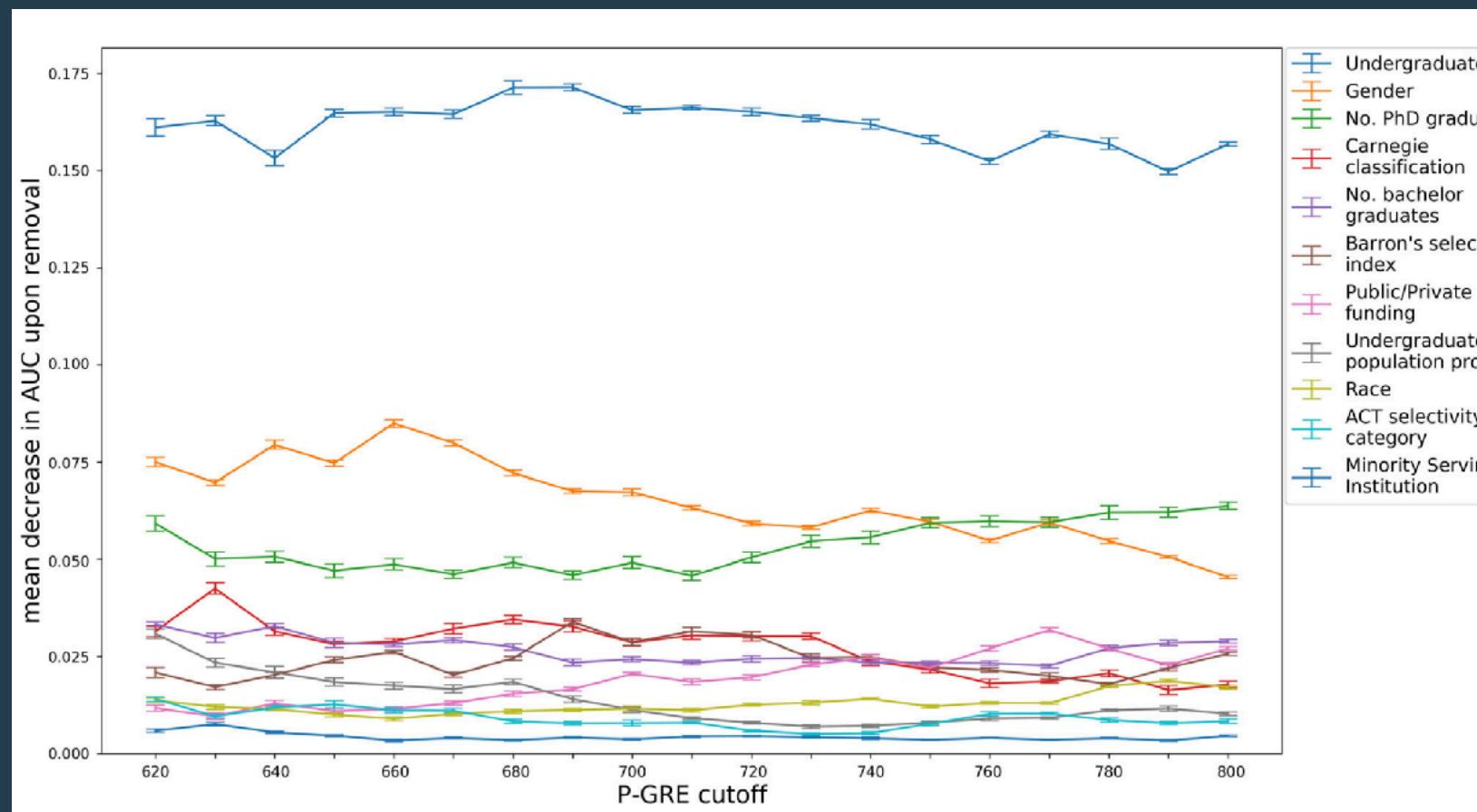
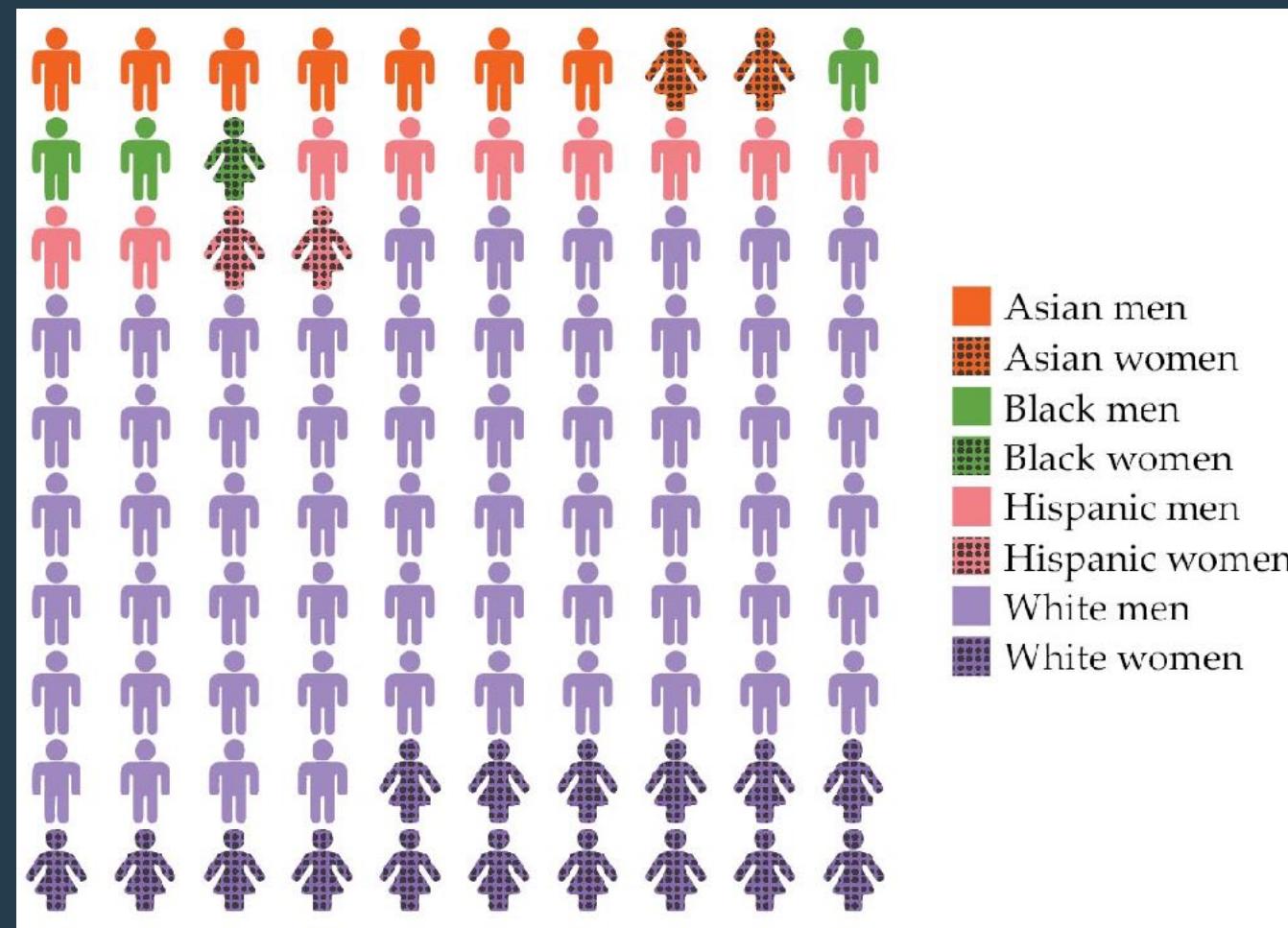


diversifying graduate physics programs

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**

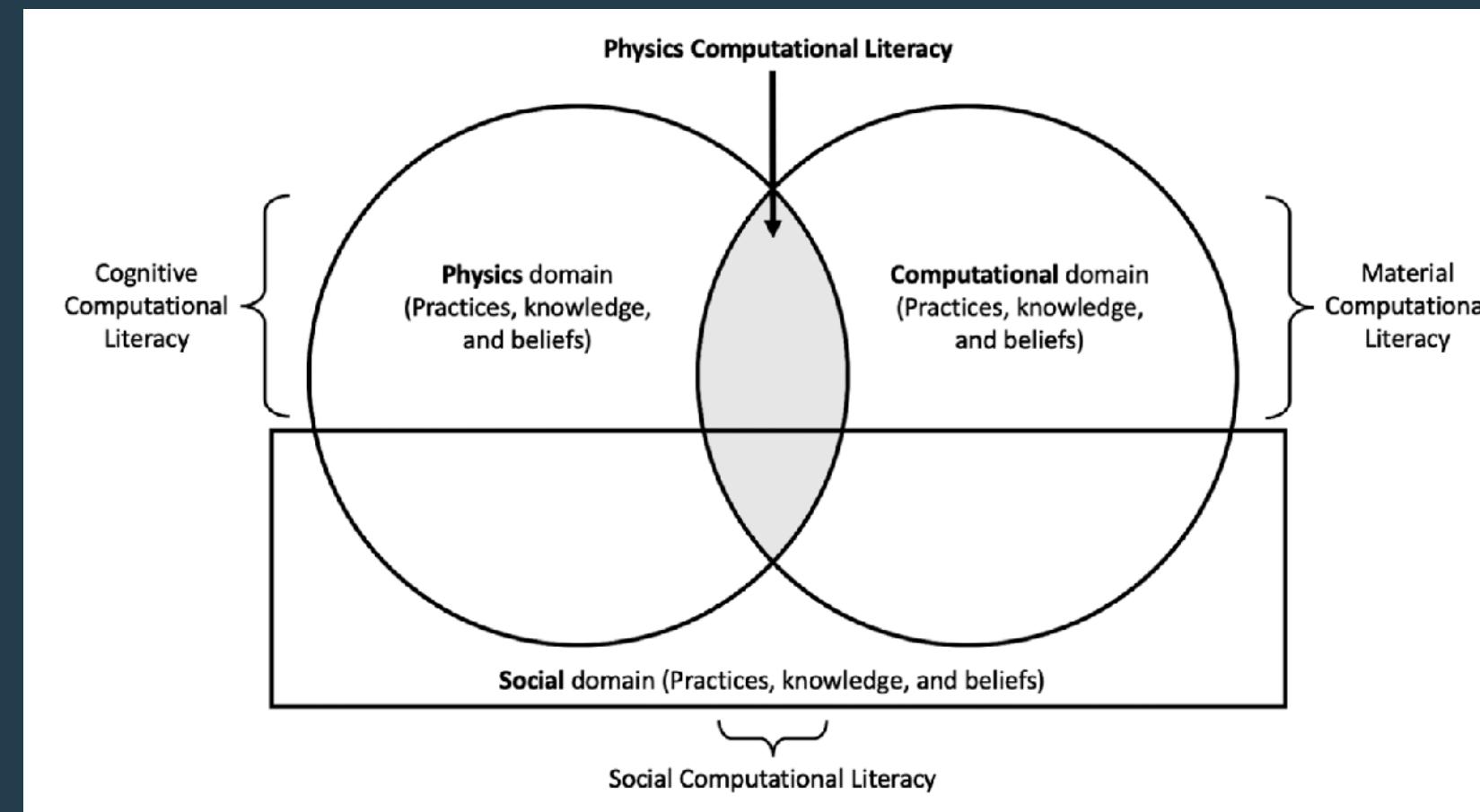
**greater diversity
across all of
science**

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

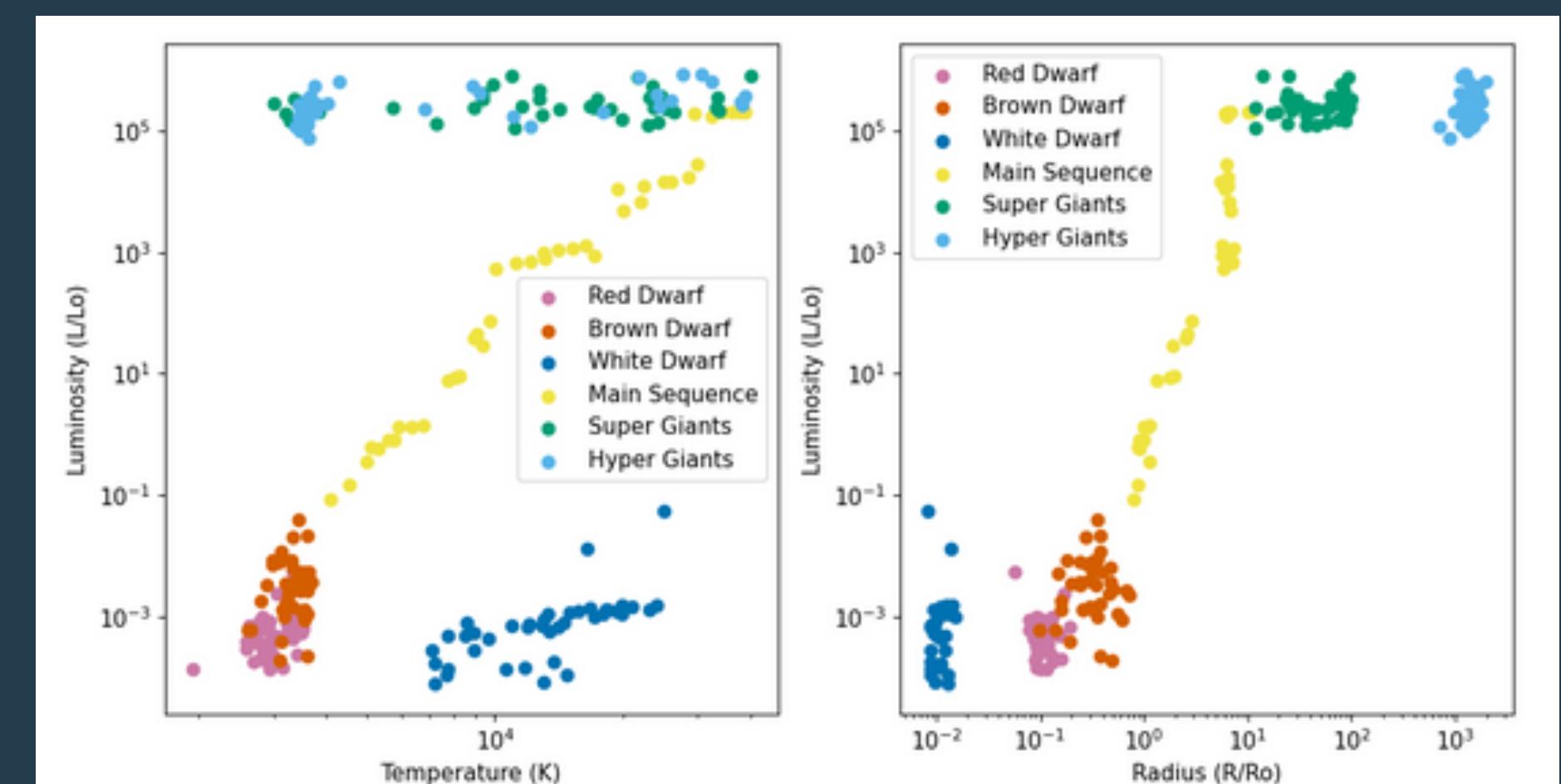
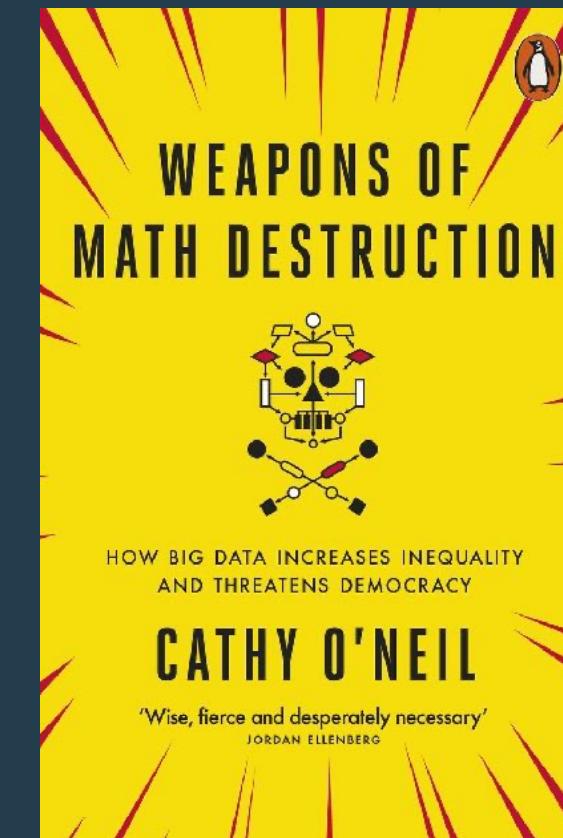
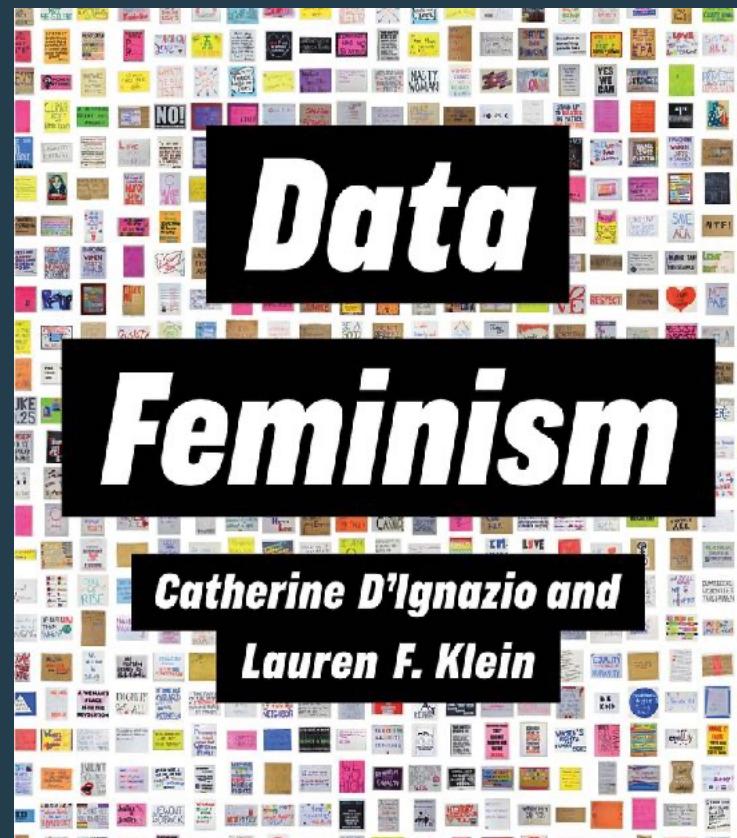
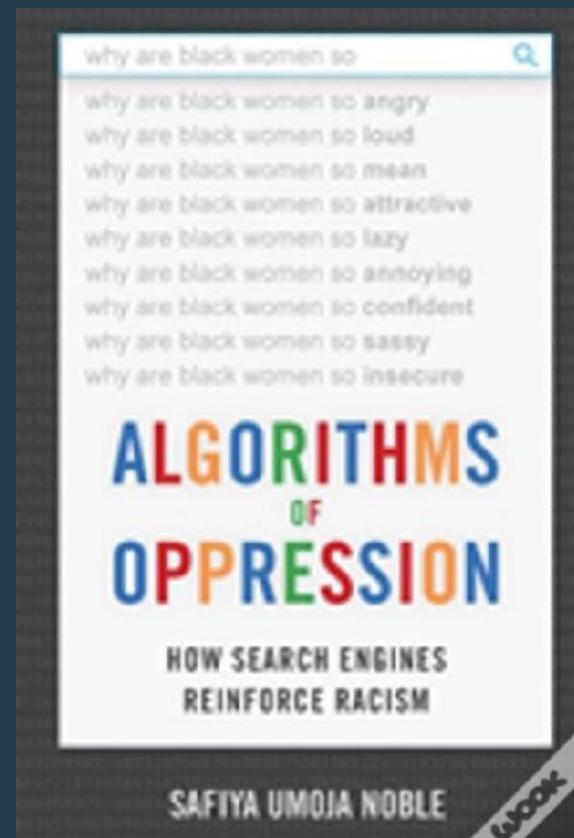


Odden, Lockwood, Caballero, Phys. Rev. PER, 2019

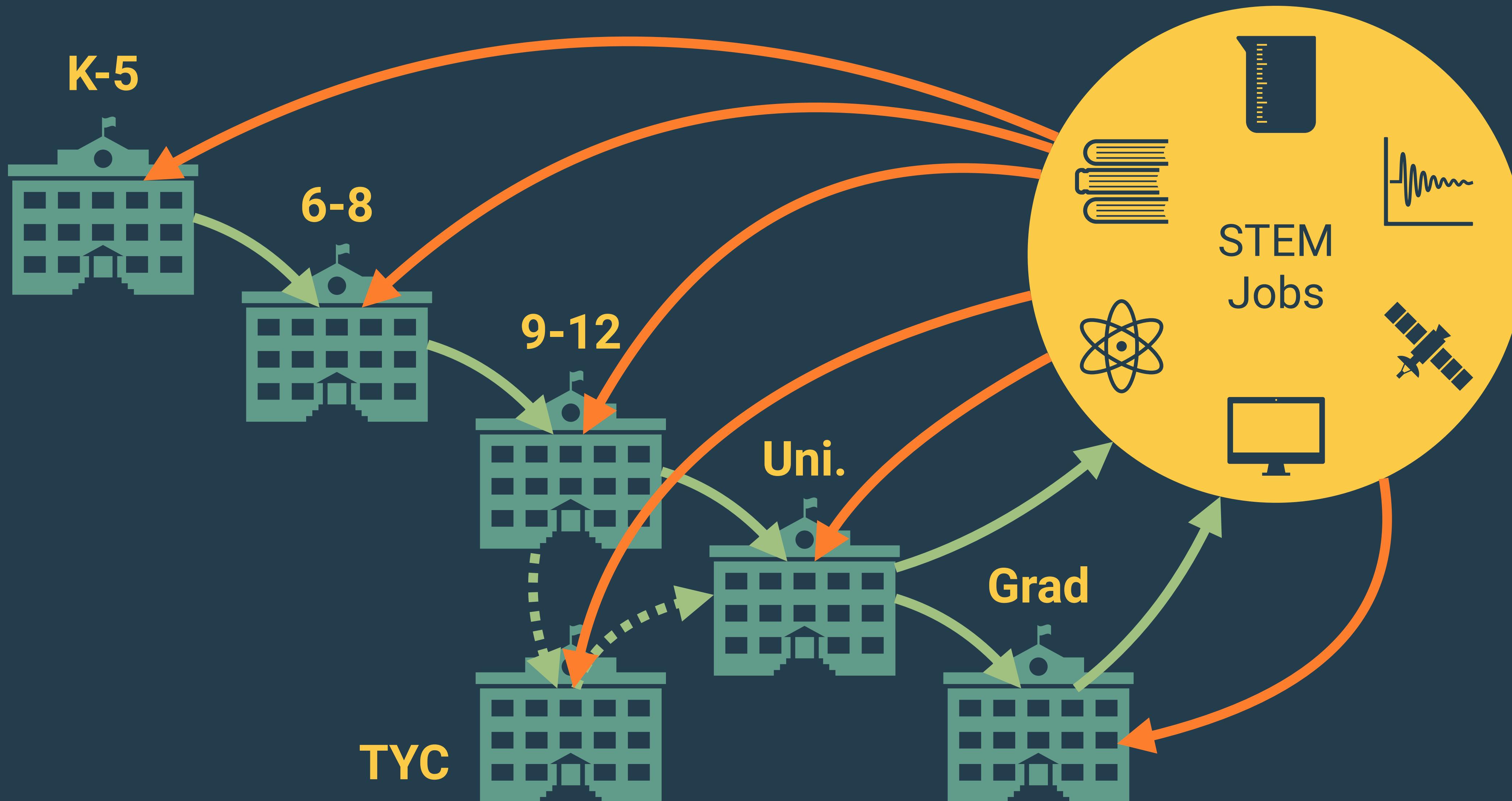
cmse 201/202
modeling,
machine learning,
& data science



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!

