

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





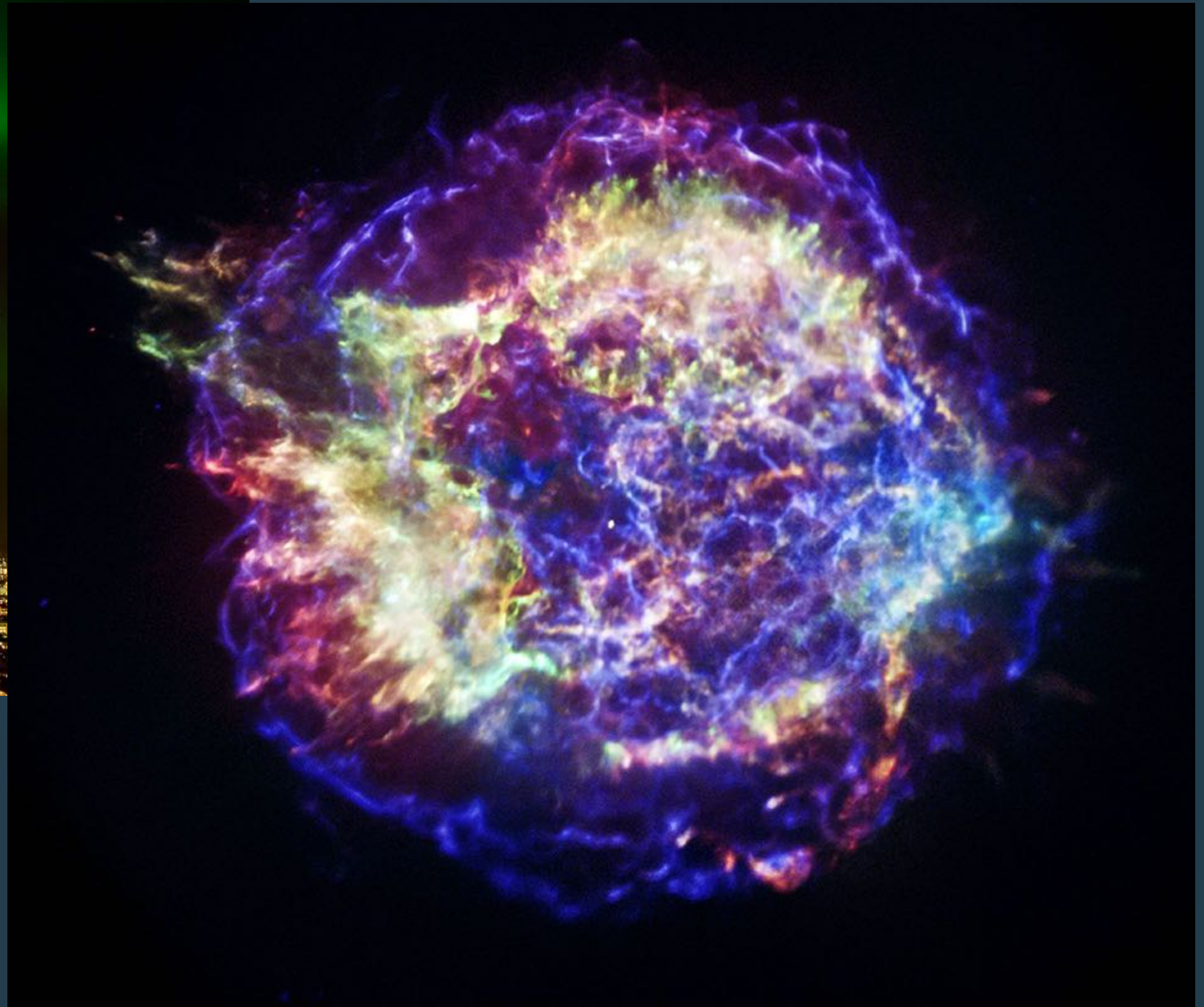
aurora borealis over oslo

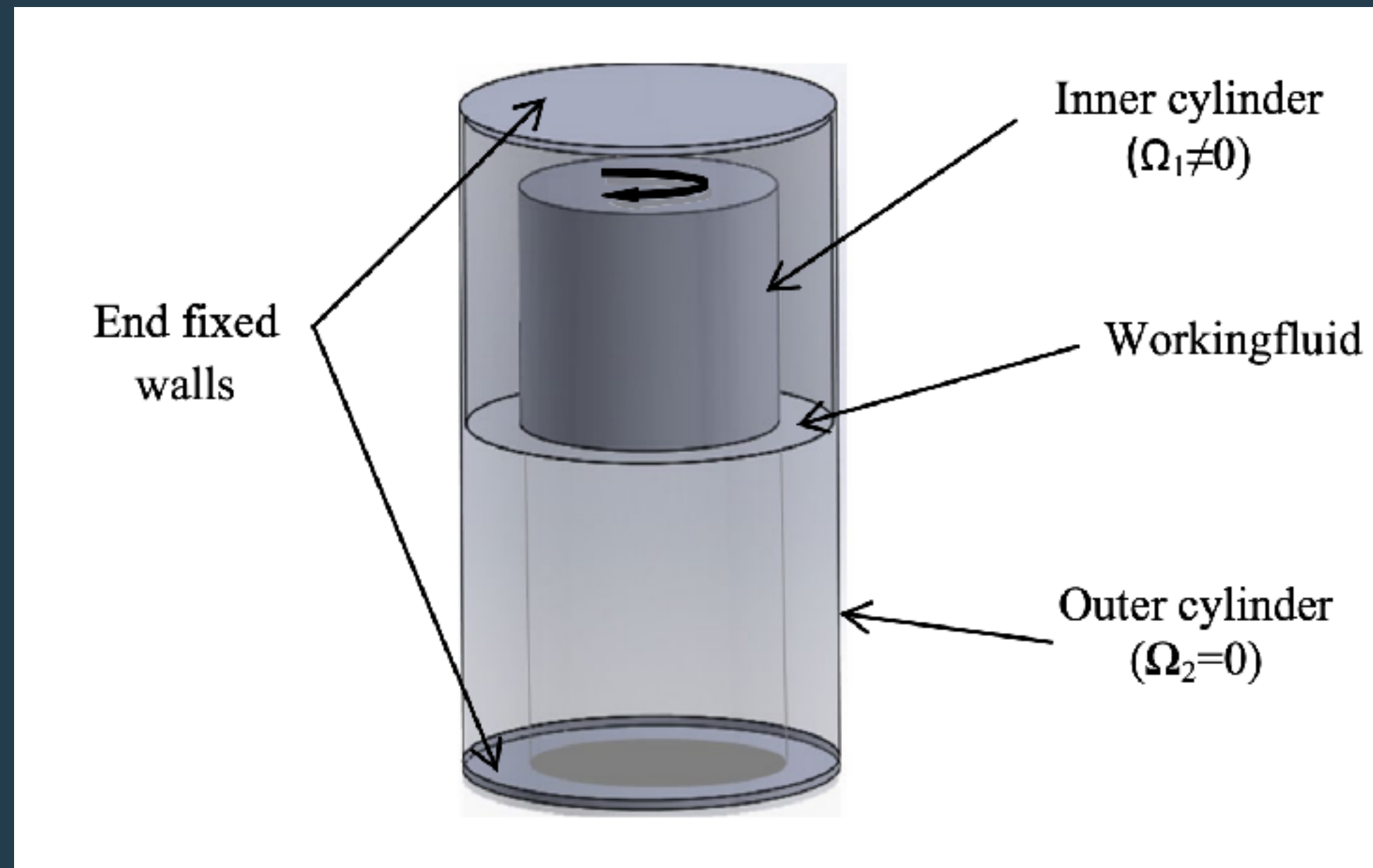
<https://www.flickr.com/photos/65218245@N00/326627830>

**science can explain
natural phenomena**

supernova remnant - cassiopeia a

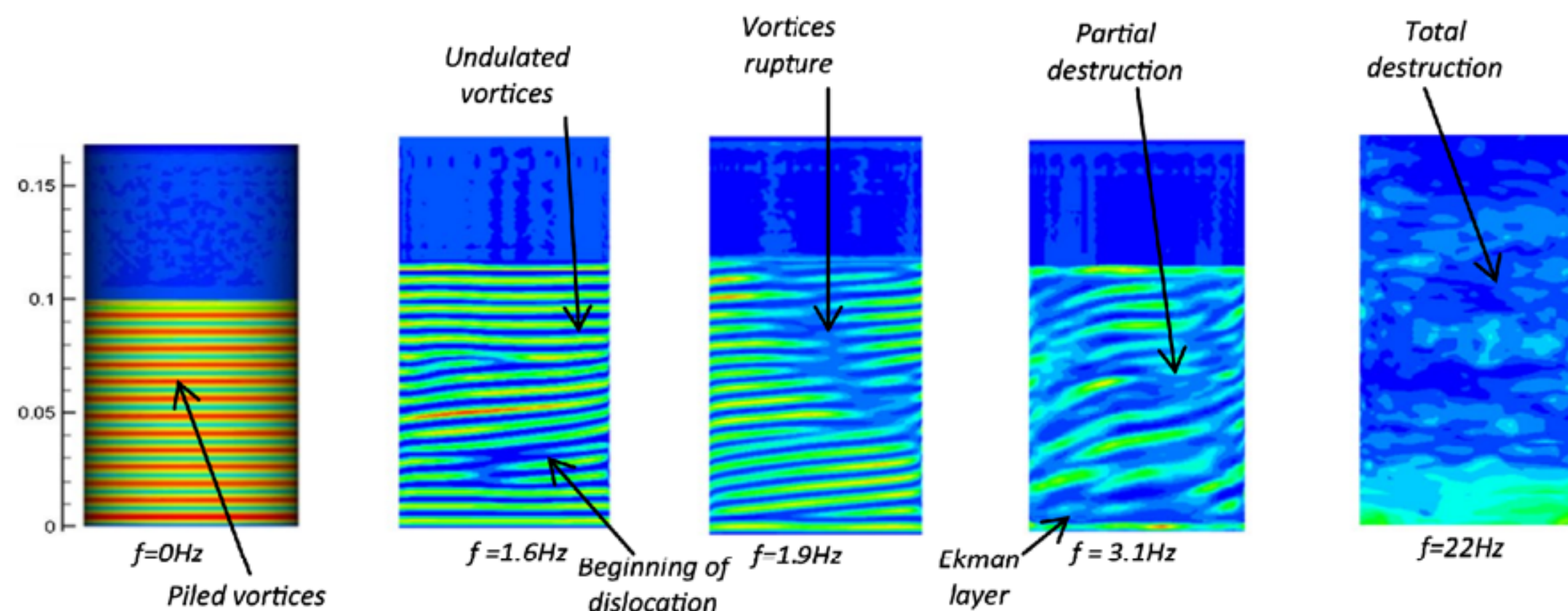
https://www.nasa.gov/mission_pages/chandra/multimedia/exploring-cassiopeiaA.html





natural transition to turbulent flow

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



taylor-couette cylinder & transition to turbulence

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

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

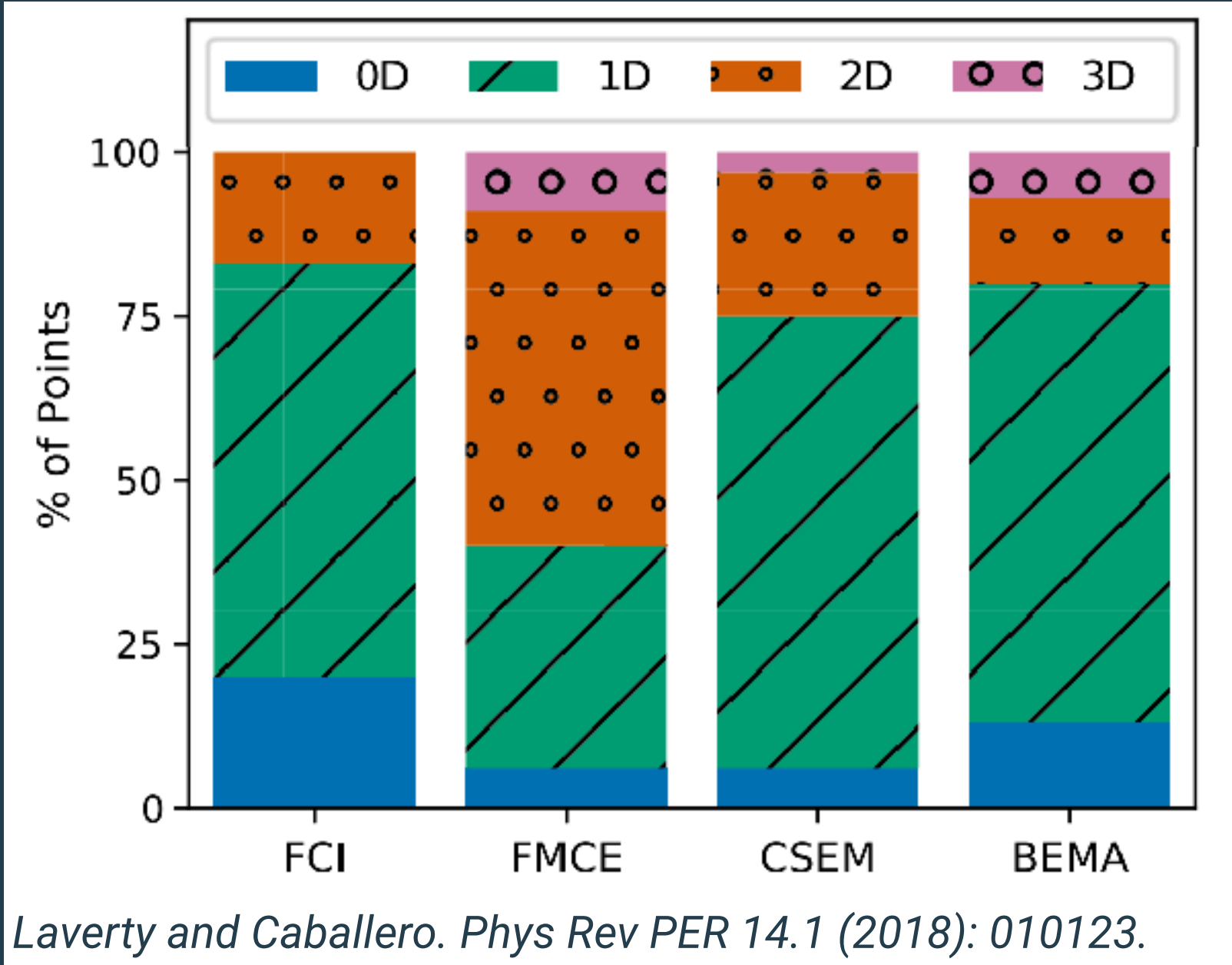
all folks can shape the work and practice of science

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)

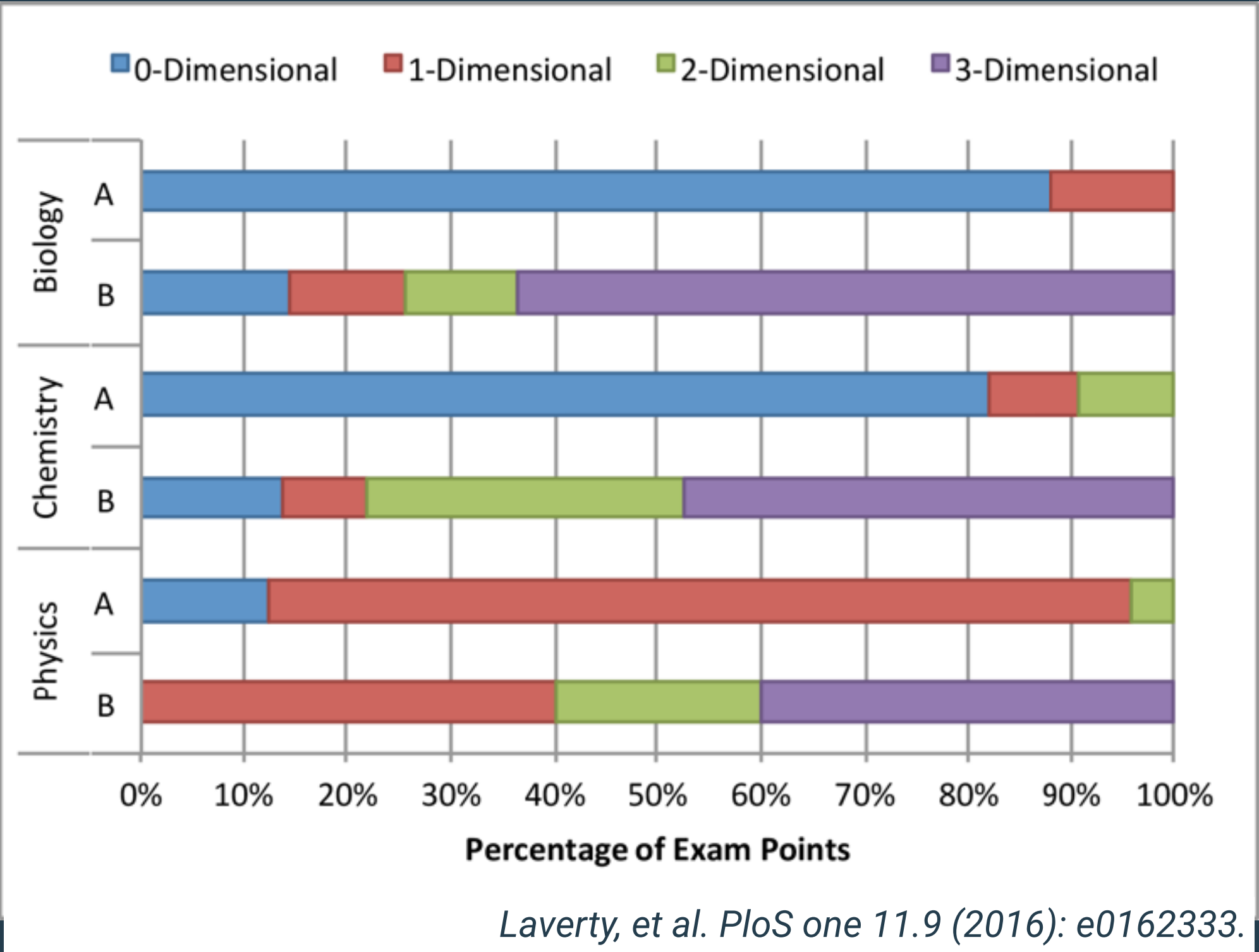
Topics	Admin	Review: Gravity, Potential Energy, Circular Motion	Intro to Kepler's Laws	Kepler's First Law	Kepler's Second Law	Kepler's Third Law	Synthesizing Kepler's Laws
Teaching Activities	Admin	CQ CQ CQ	Lecture			CQ CQ	Lecture
SP		None	None	None	None	None	None
CI		-	-	-	-	-	-
CC		-	-	-	-	Bain, et al. PLoS One 15.6 (2020): e0234640.	



active learning is not necessarily 3d learning



three-dimensional learning assessment protocol (3DLAP)



developing community-based courses

projects and practices in physics

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

Projects & Practices in Physics
a community-based learning environment

Trace: 63_projects > project_1s > start > project_3_2015_semester_1

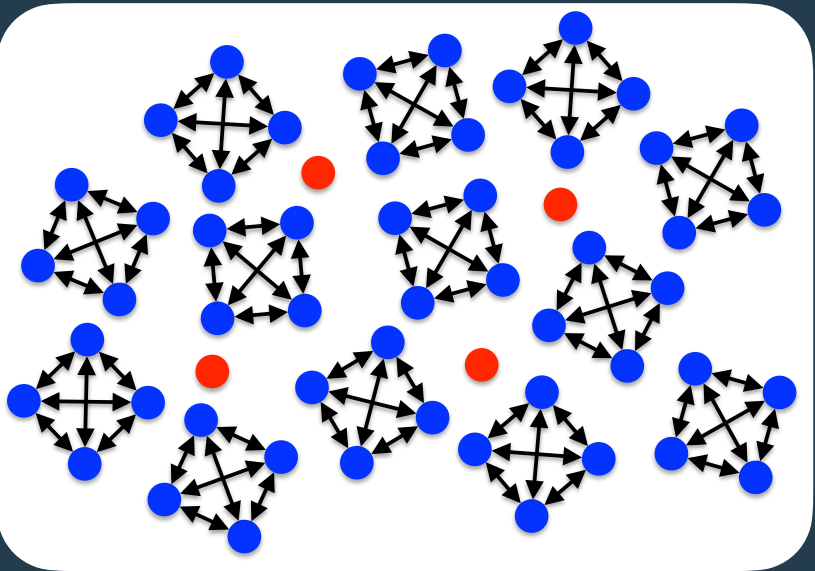
Project 3: Geosynchronous Orbit: Part A

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 15×10^3 kg. Your simulation should be generalized enough to model other types of orbits including elliptical ones.

Codes for Project 3:
physync.py
PhysUI Module



```
# 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
    r=10000

    Satellite.pos = Satellite.pos + pSatellite/mSatellite*deltat

    SatelliteMotionMap.update(t, pSatellite/mSatellite)

    t = t + deltat
```

computing



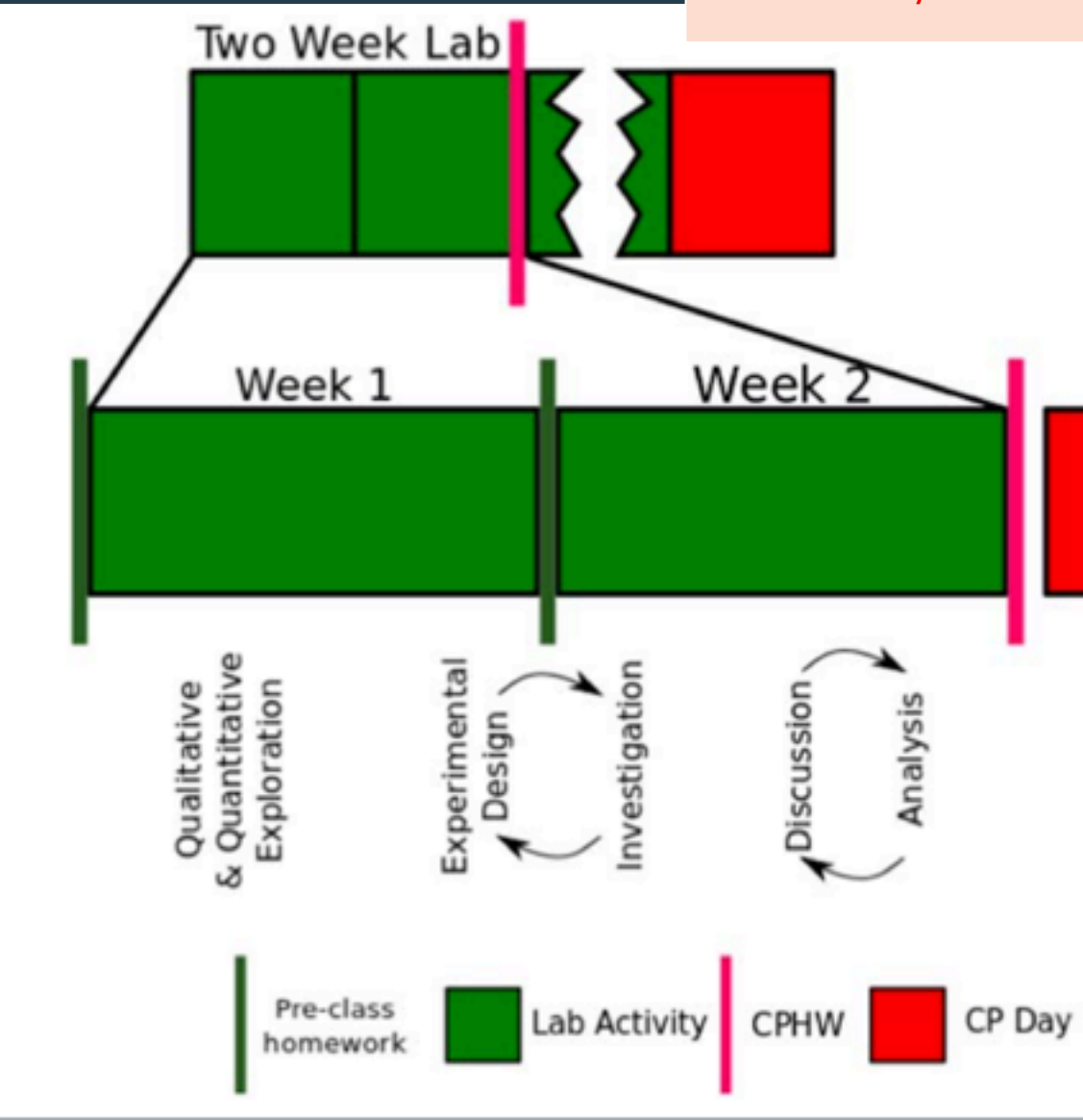
MICHIGAN STATE
UNIVERSITY



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

HHMI
HOWARD HUGHES MEDICAL INSTITUTE

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



Polarization

Sydney Kerre
Catherine, Kate, Ryan
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 lessen haze. Polarizers work by blocking out every direction that light waves point in from a source and only 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

- Observed a light source through a single polarizer and then a second one.
- Measured Malus' Law by placing a detector at the end of both polarizers (Fig. 1.1) and quantitatively measuring the intensity of the light coming through (Fig. 1.2).
- Measured the intensity of only the first polarizer and determined how varying angles would change this.
- Created a model to account for the intensity of the light as it comes from the source, passes through the first polarizer, and passed through the second.

Conclusion

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 polarizer. 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 appeared.

The model we synthesized is:
 $I = (I_0/2) \cos^2(\theta_2 - \theta_1)$ (uncertainty of +/- 10)

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.

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 value would be.

- Understand the relationship between the intensity of the light source and the angle of the polarizer
- Determine the result of manipulating the angles of polarizer 1 and polarizer 2.
- Determine sources and values for uncertainty.
- Create a model to understand exactly what is happening to the initial unpolarized light as it passes through two polarizers.

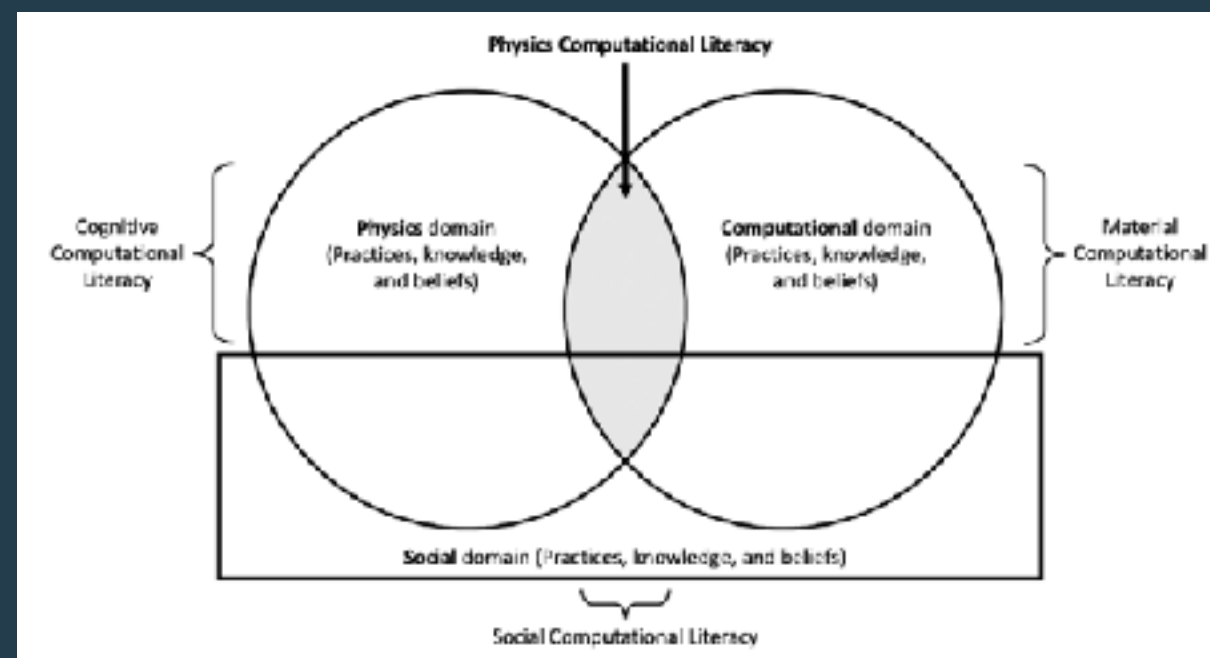
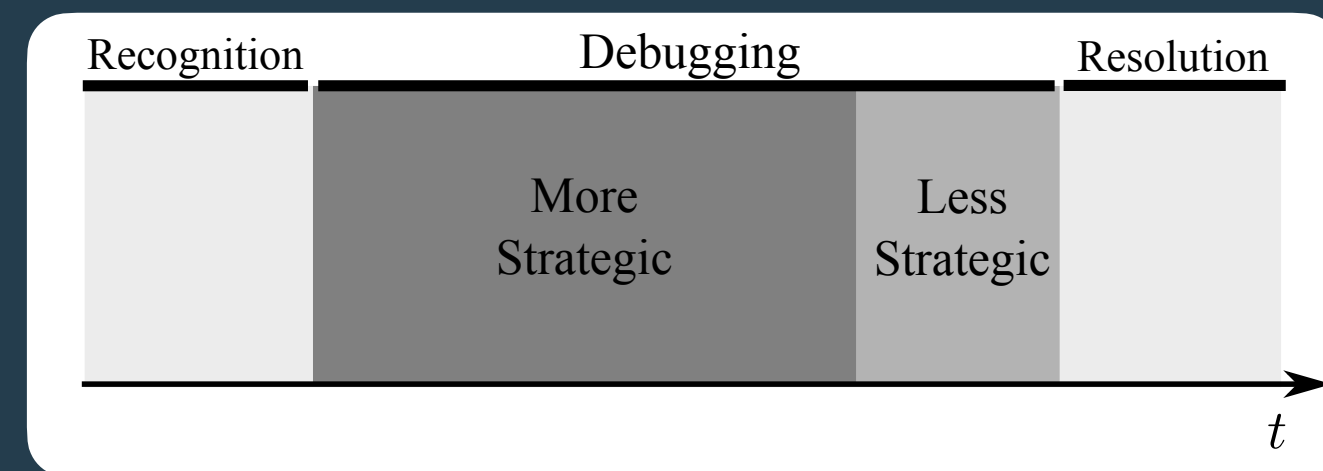
References

Figure 1.2: An inverse relationship: as the angle of the second polarizer increases, the intensity decreases. At about 75°, the light is blue. In a linear model, the graph is opposite with a slope of 75.411 +/- .355 and a y-intercept of 3.759 +/- .221.

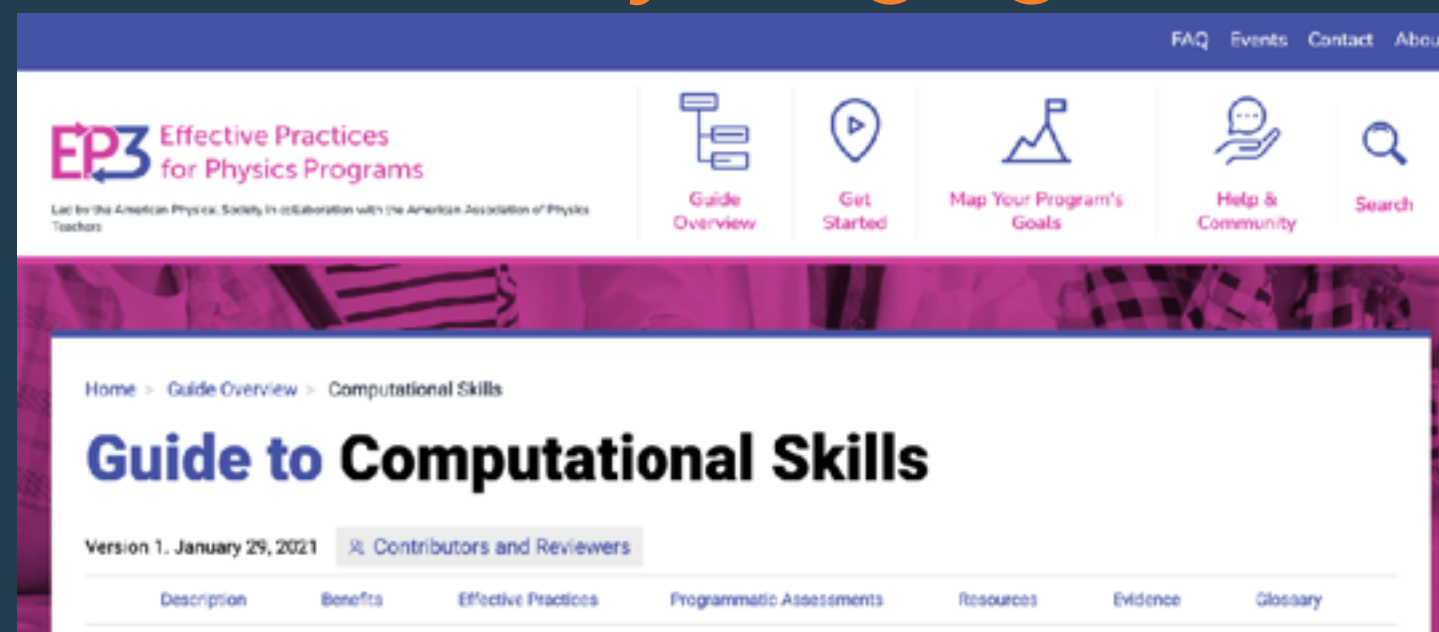
Funding Source: Michigan State University; Dr. William Martinez and Kelsey Funkhouser

integrating computing in physics

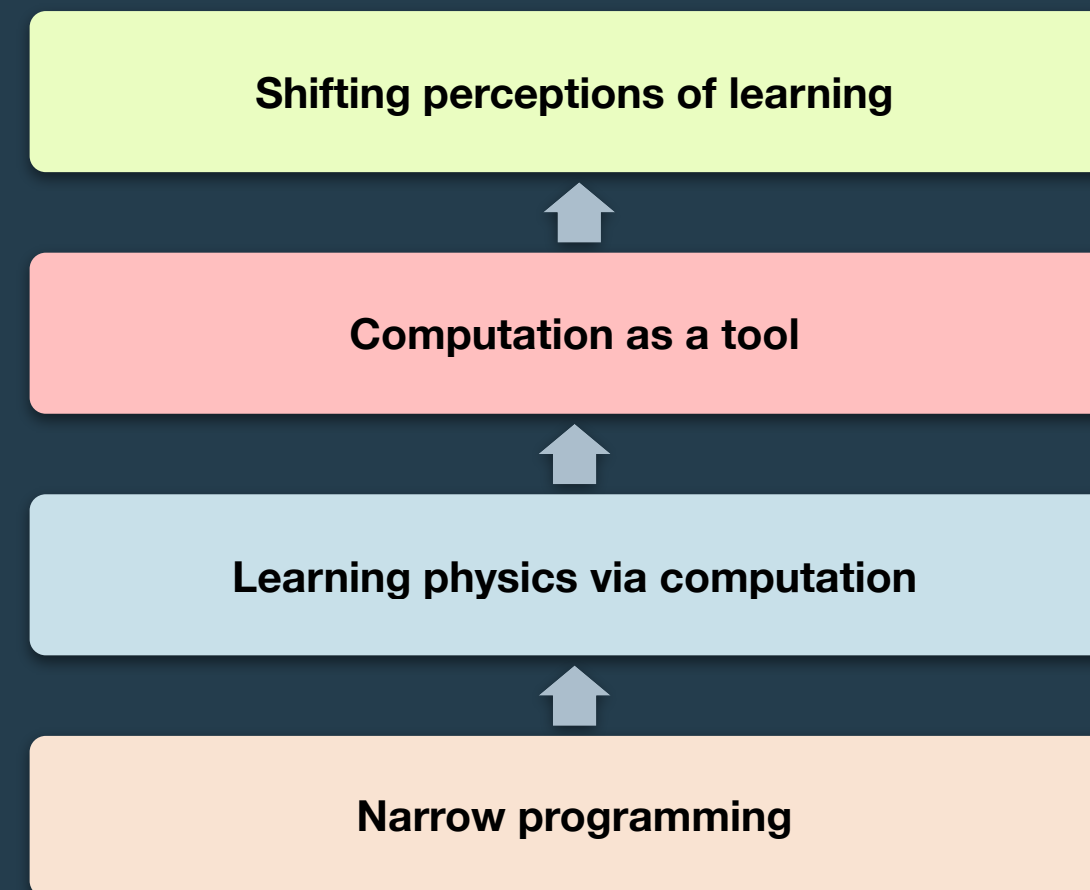
research



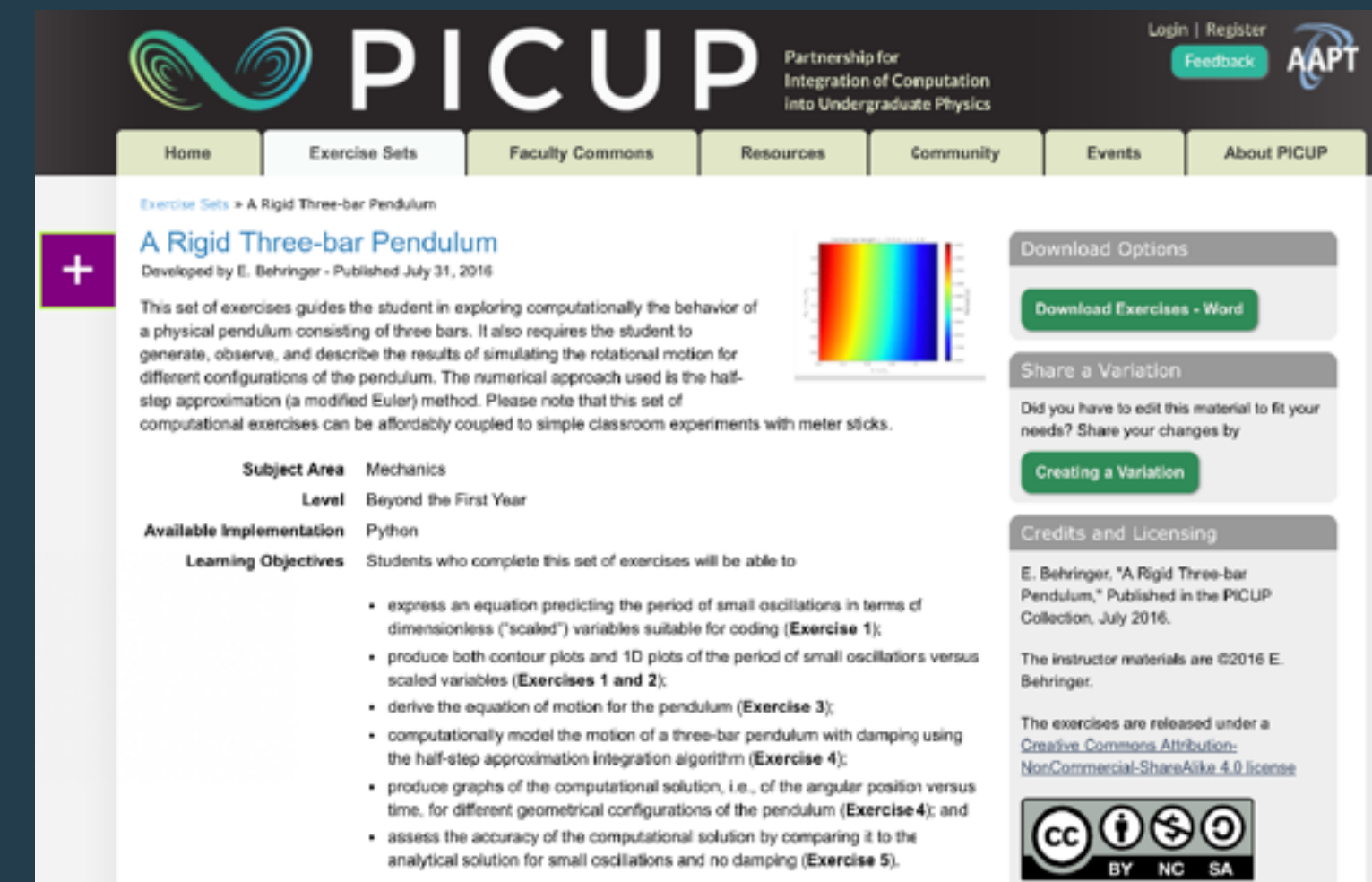
community engagement



faculty learning community



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



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



department-wide efforts

Caballero & Hjorth-Jensen, 2018

[illegible]

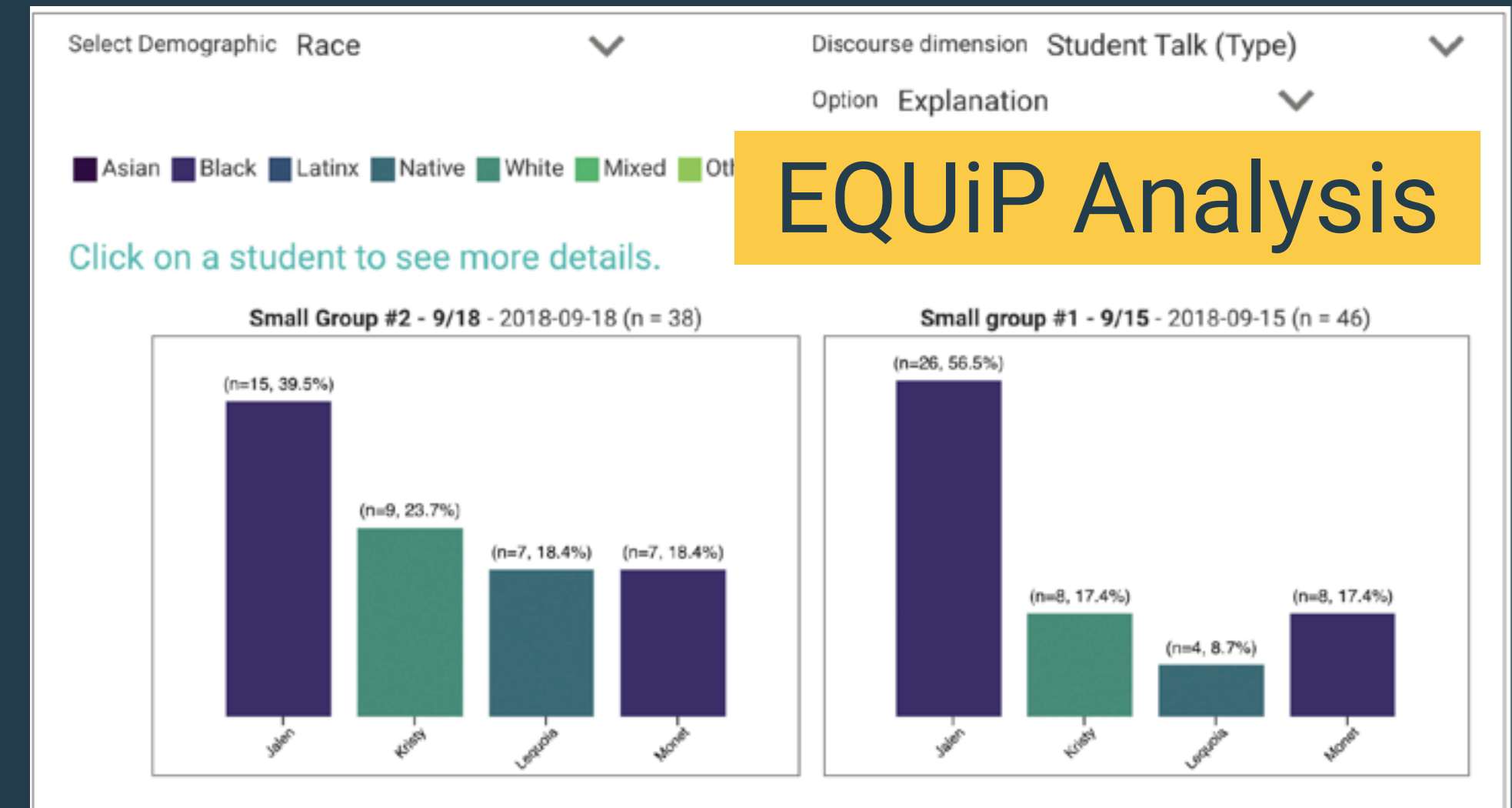
supporting pre-college physics educators



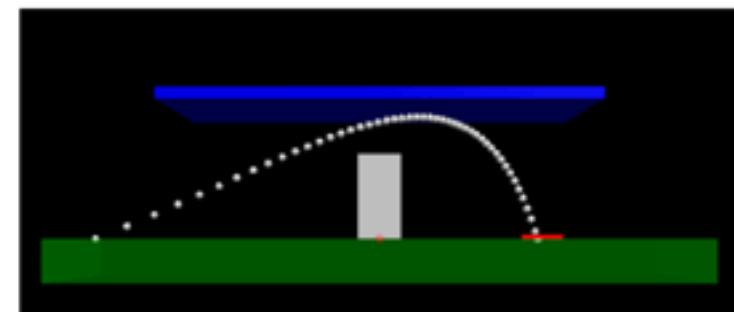
create a **computational model** to calculate...

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.msperl.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.

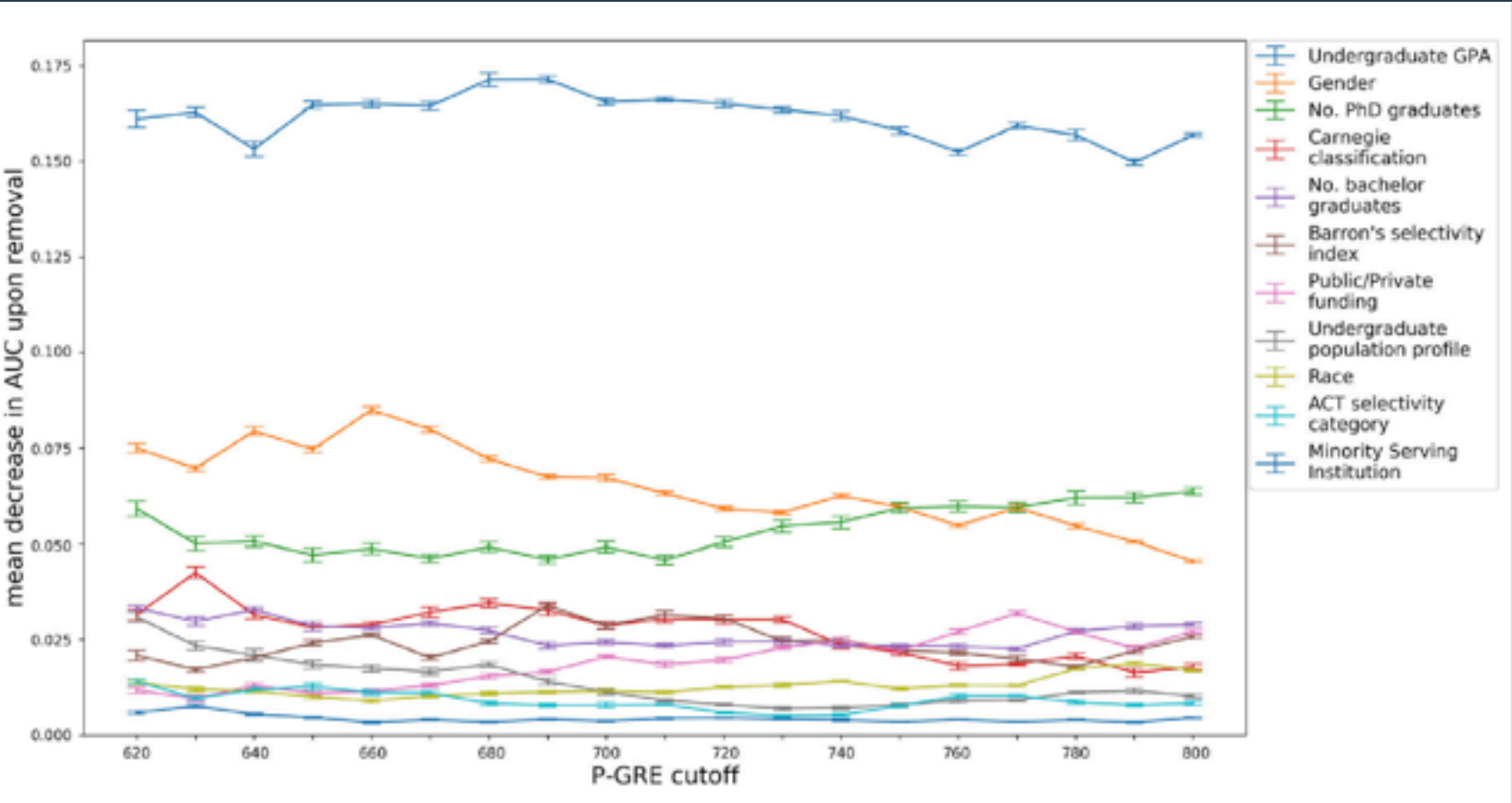
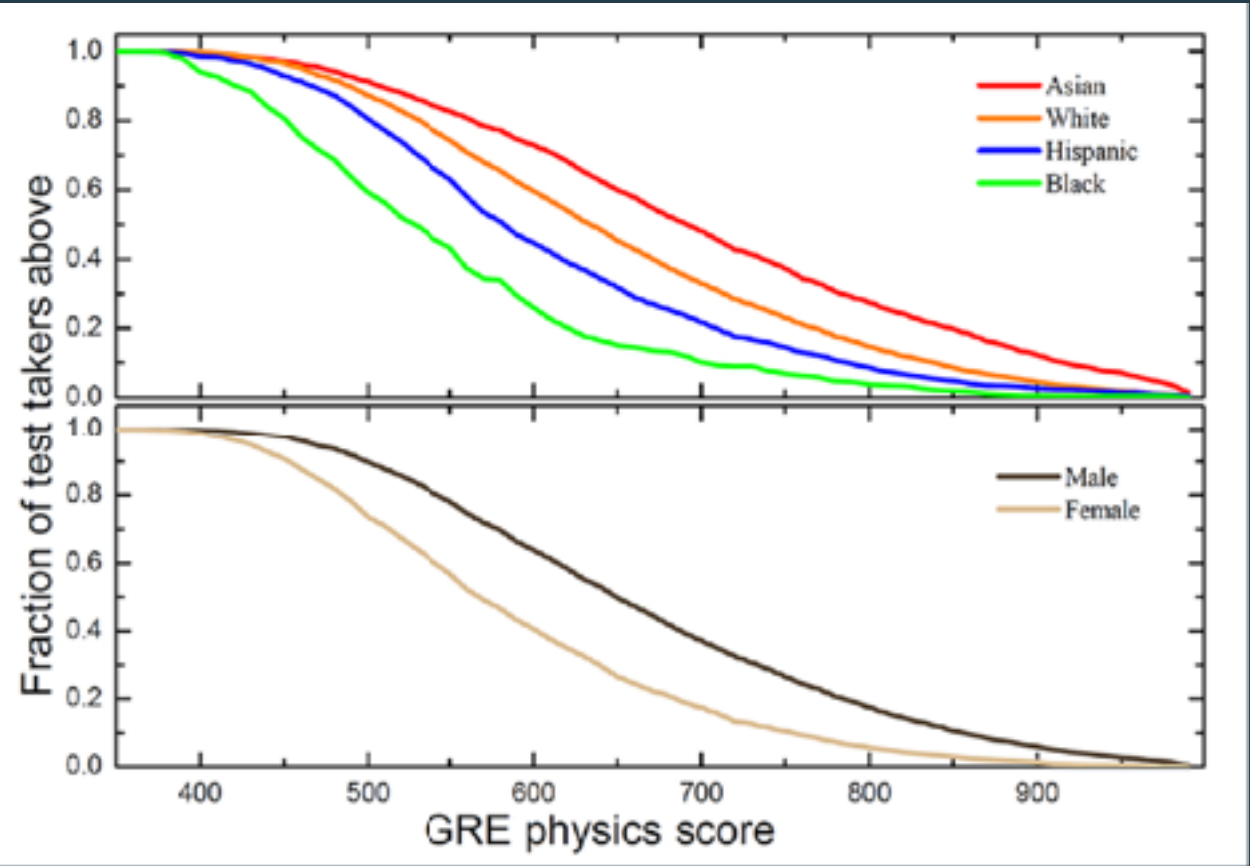
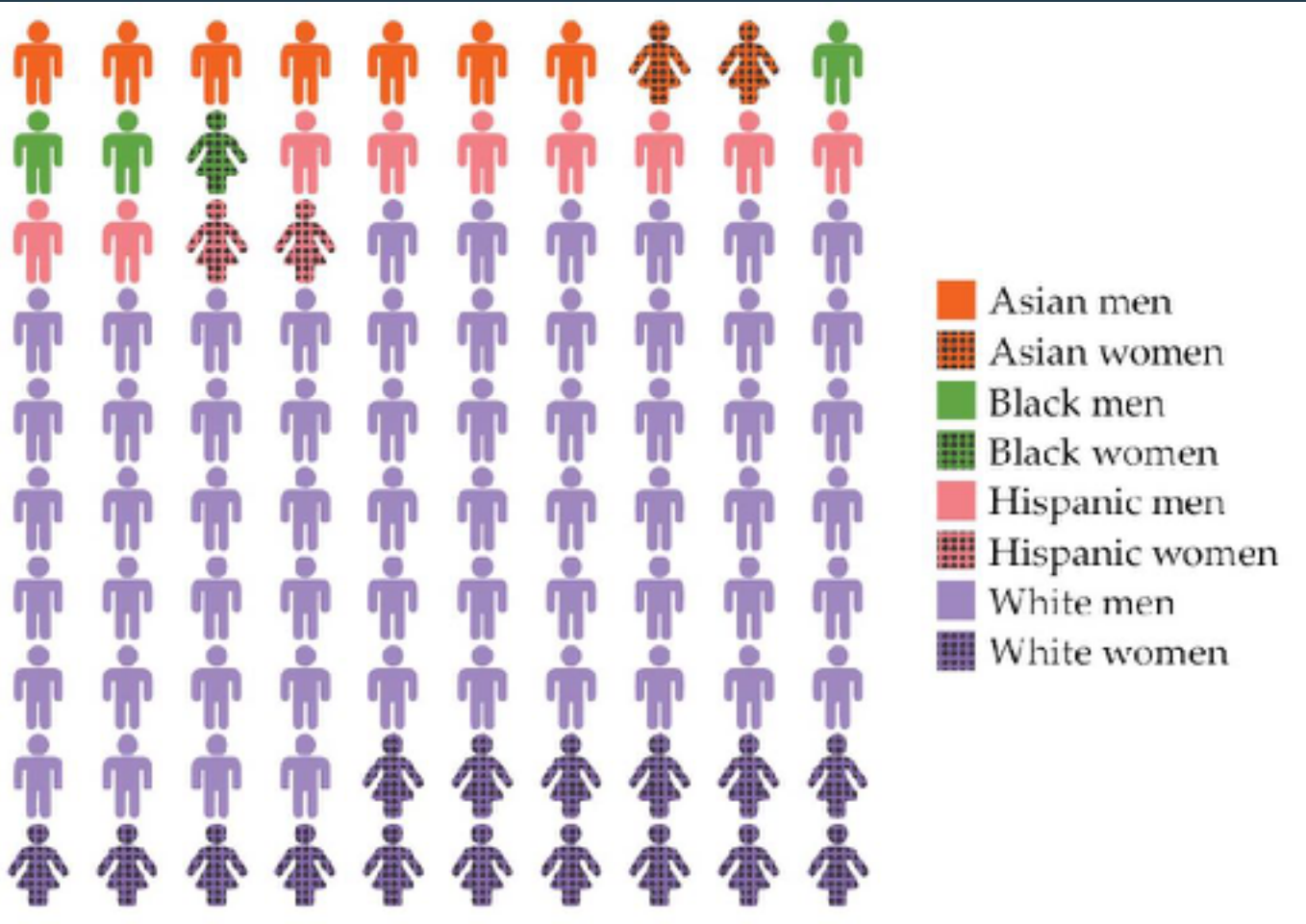
equip.ninja
Christensen, et. al. TPT 60.6 (2022): 414-418.



diversifying graduate physics programs

potential physics phd applicants

using holistic admissions rubric



disaggregated gre distribution

gre cutoffs
limit diversity

		Most common rubric score		
		Low	Medium	High
ACADEMIC PREPARATION	Physics coursework	✗		✓
	Math coursework		✗	✓
	All other coursework			✓✗
	Academic honors	✗		✓
RESEARCH EXPERIENCE	Variety/duration of research			✓✗
	Quality of work		✗	✓
	Technical skills		✗	✓
	Research dispositions		✗	✓
NONCOGNITIVE COMPETENCIES	Achievement orientation		✗	✓
	Conscientiousness		✗	✓
	Initiative		✗	✓
	Perseverance		✗	✓
FIT WITH PROGRAM	Alignment of research		✗	✓
	Alignment with faculty		✗	✓
	Community contributions		✗	✓
	Diversity contributions	✗		✓
GRE SCORES	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

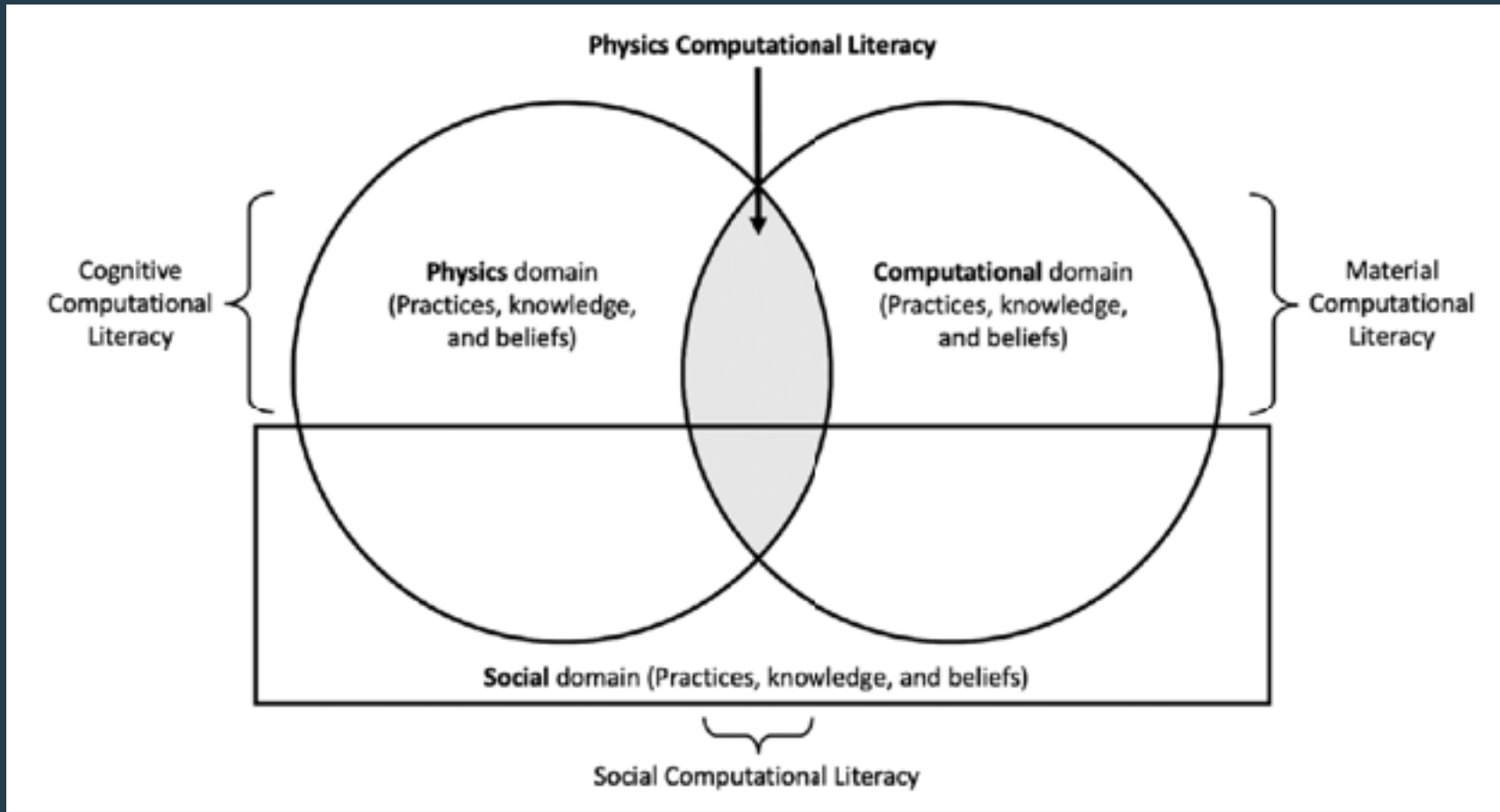
greater diversity
across all of
science

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

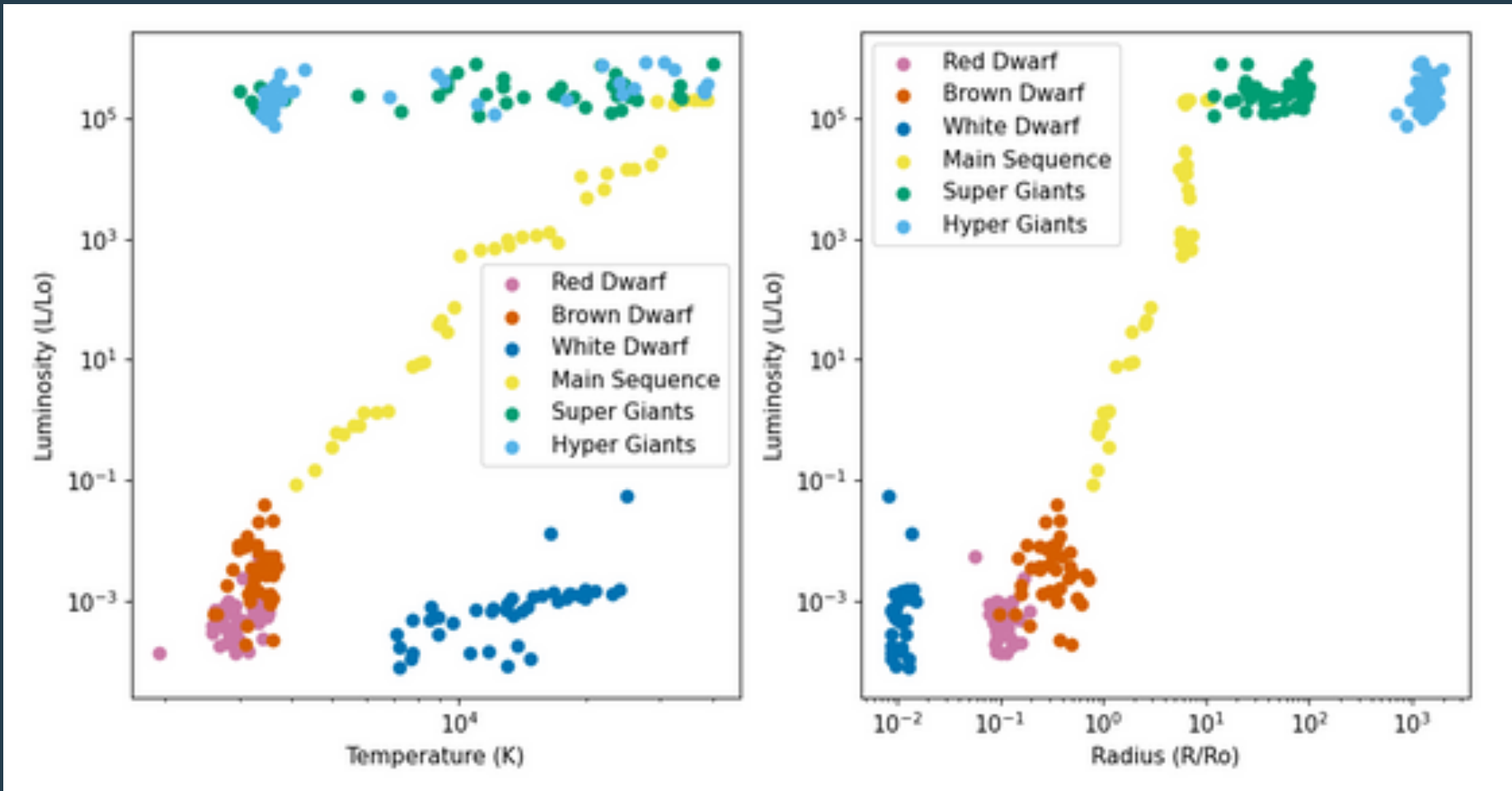
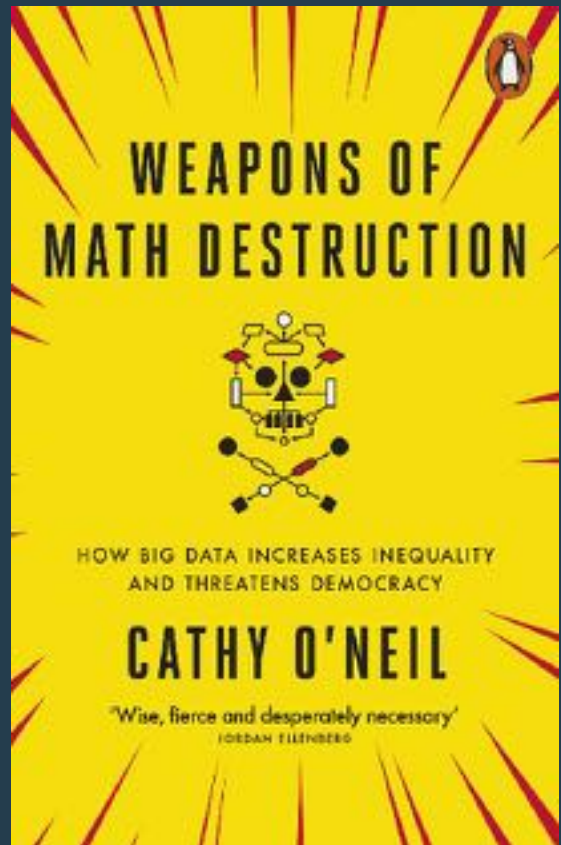
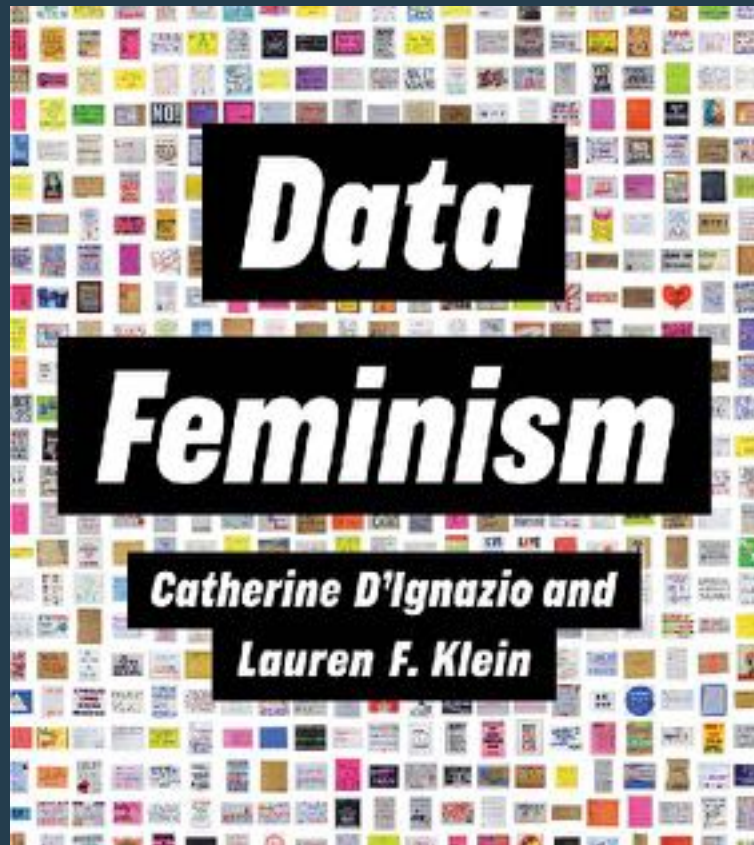
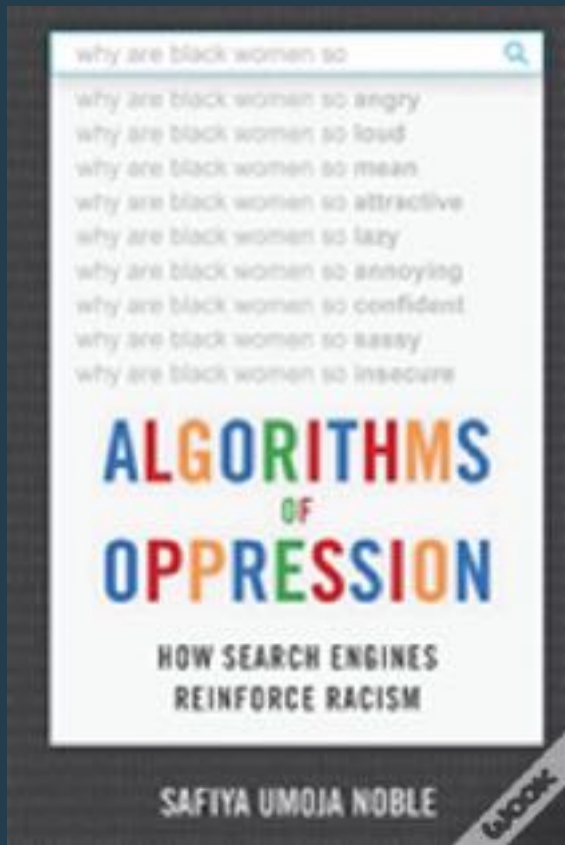


Odden, Lockwood, Caballero, Phys. Rev. PER, 2019

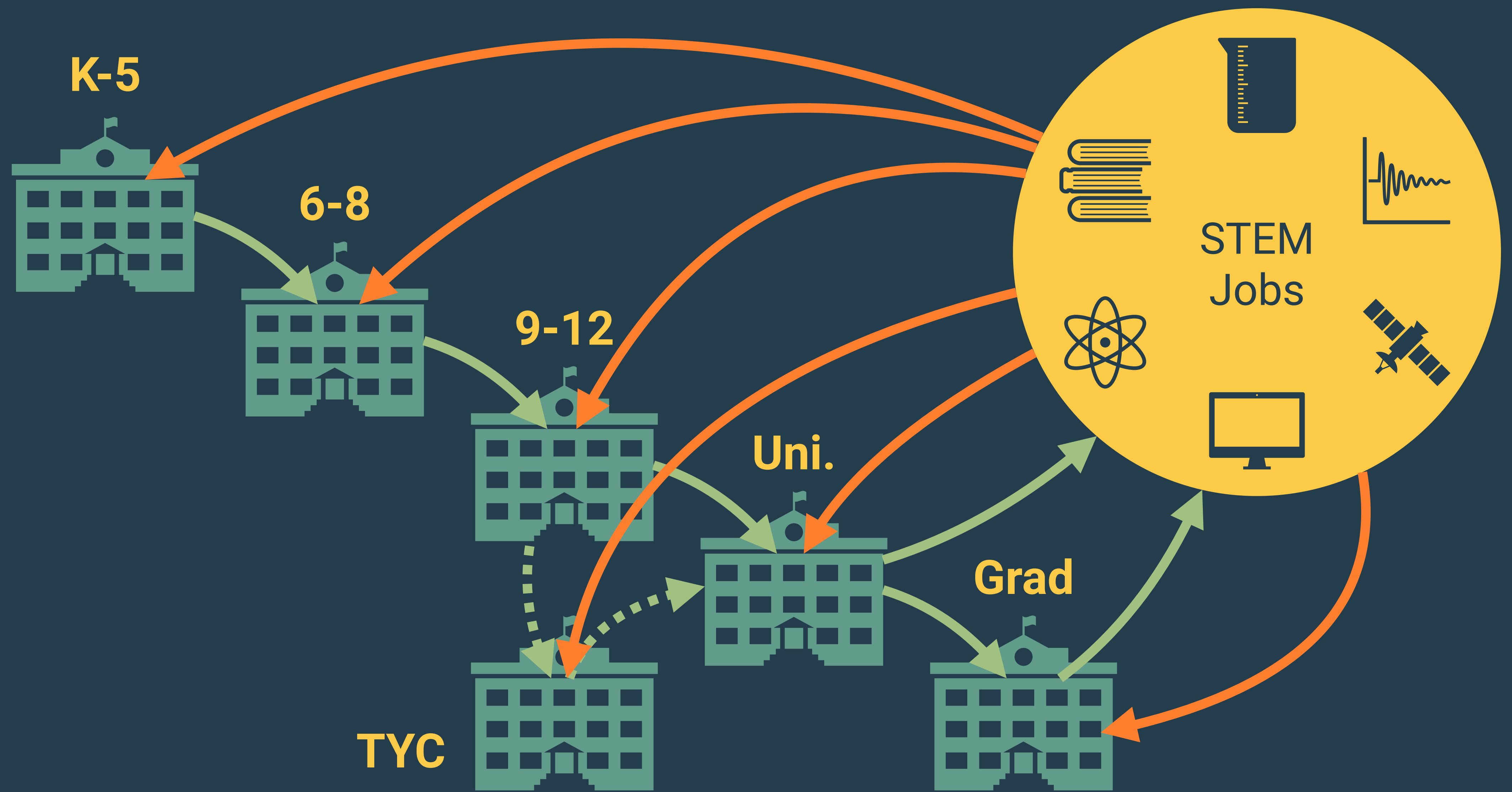
cmse 201/202
modeling,
machine learning,
& data science



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!