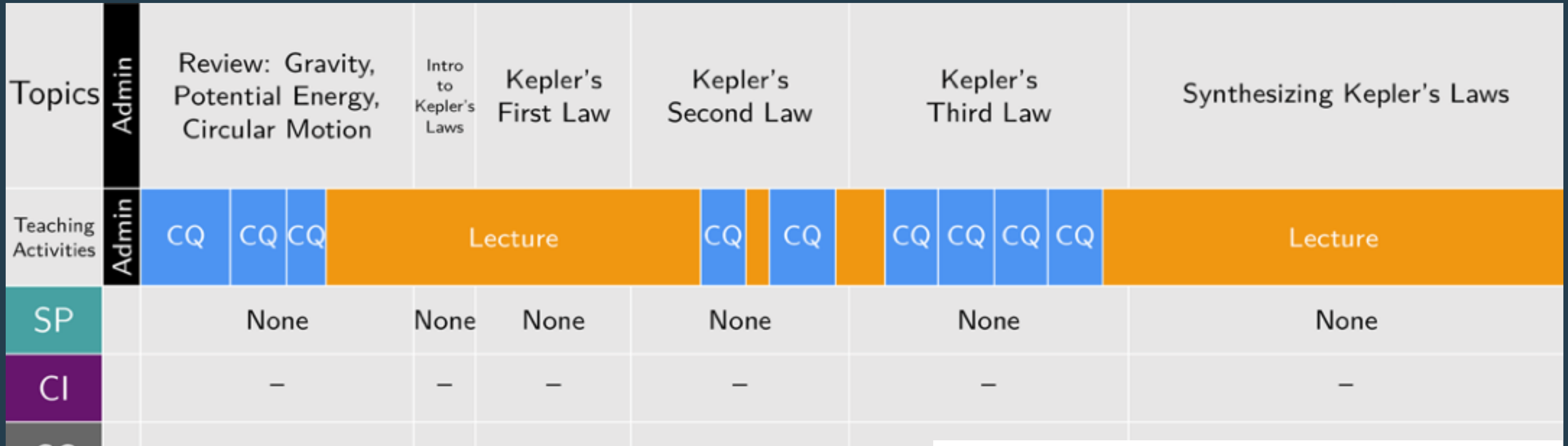
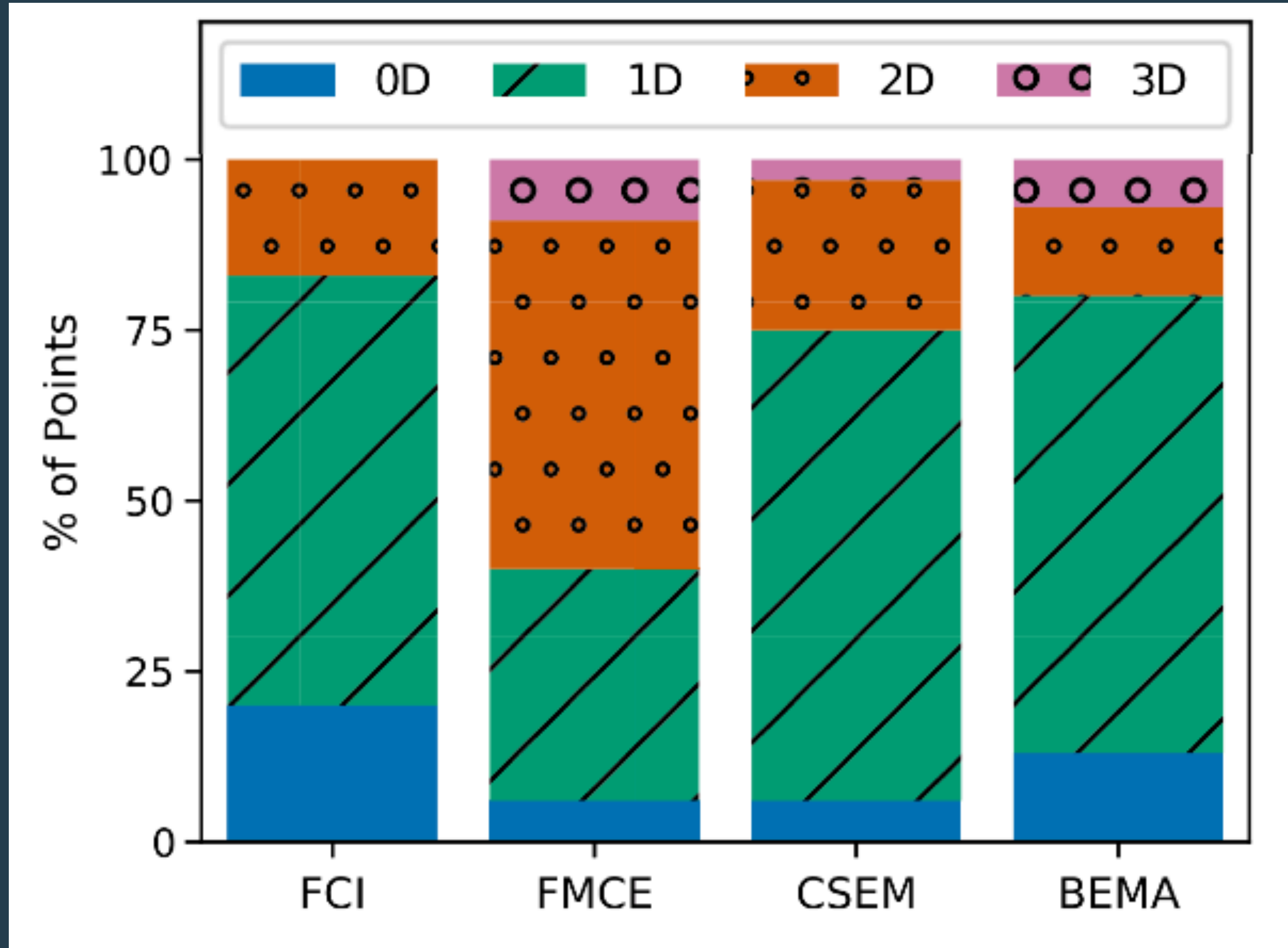
moving beyond active learning

three-dimensional learning observation protocol (3DLOP)



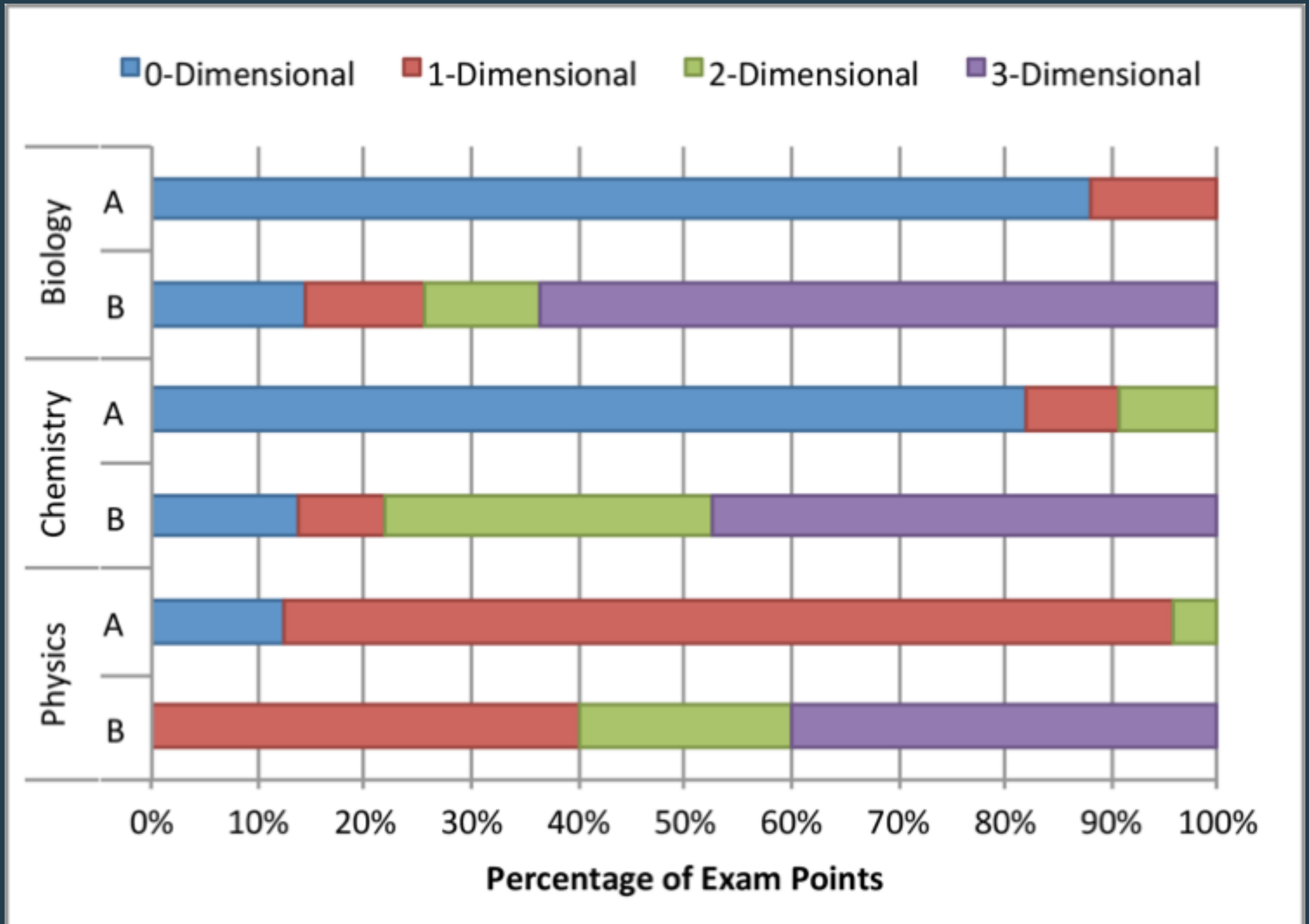
Bain, et al. PLoS One 15.6 (2020): e0234640.



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

active learning is not necessarily 3d learning

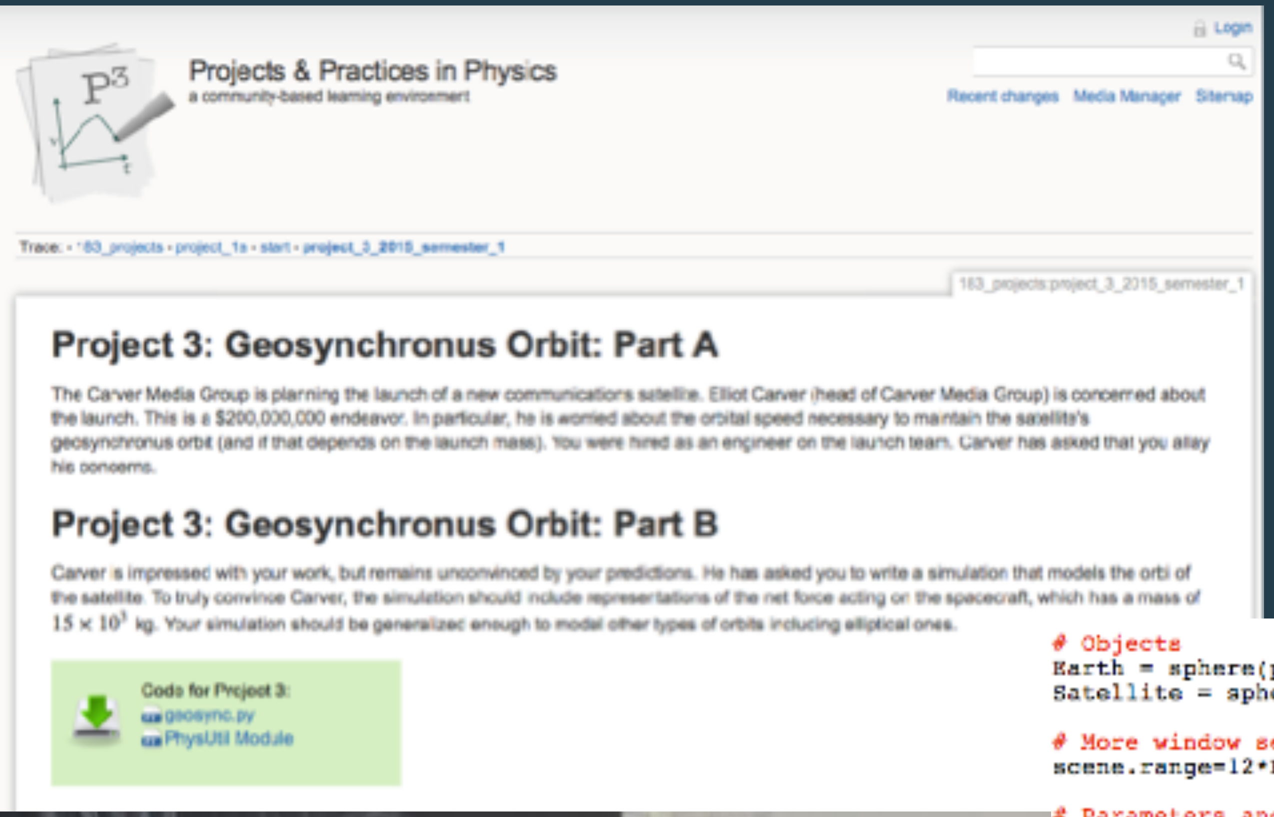
three-dimensional learning assessment protocol (3DLAP)

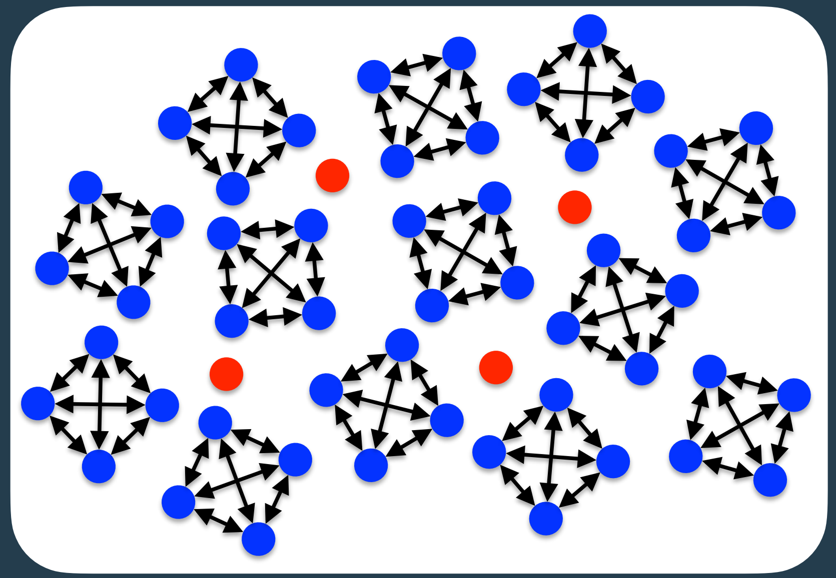


Laverty, et al. PloS one 11.9 (2016): e0162333.

developing community-based courses

projects and practices in physics





```
# 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
    rate(10000)

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

    SatelliteMotionMap.update(t, pSatellite/mSatellite)

    t = t + deltat
```

computing

group-based

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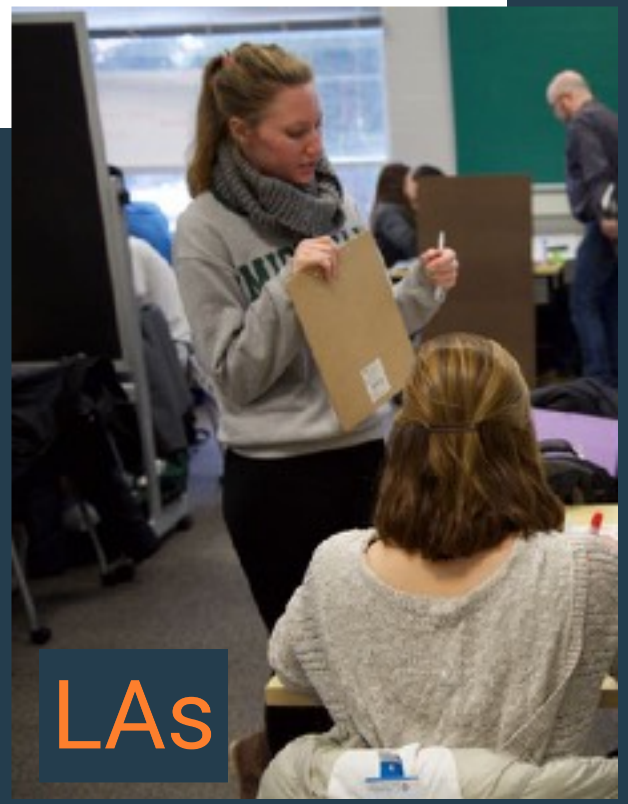
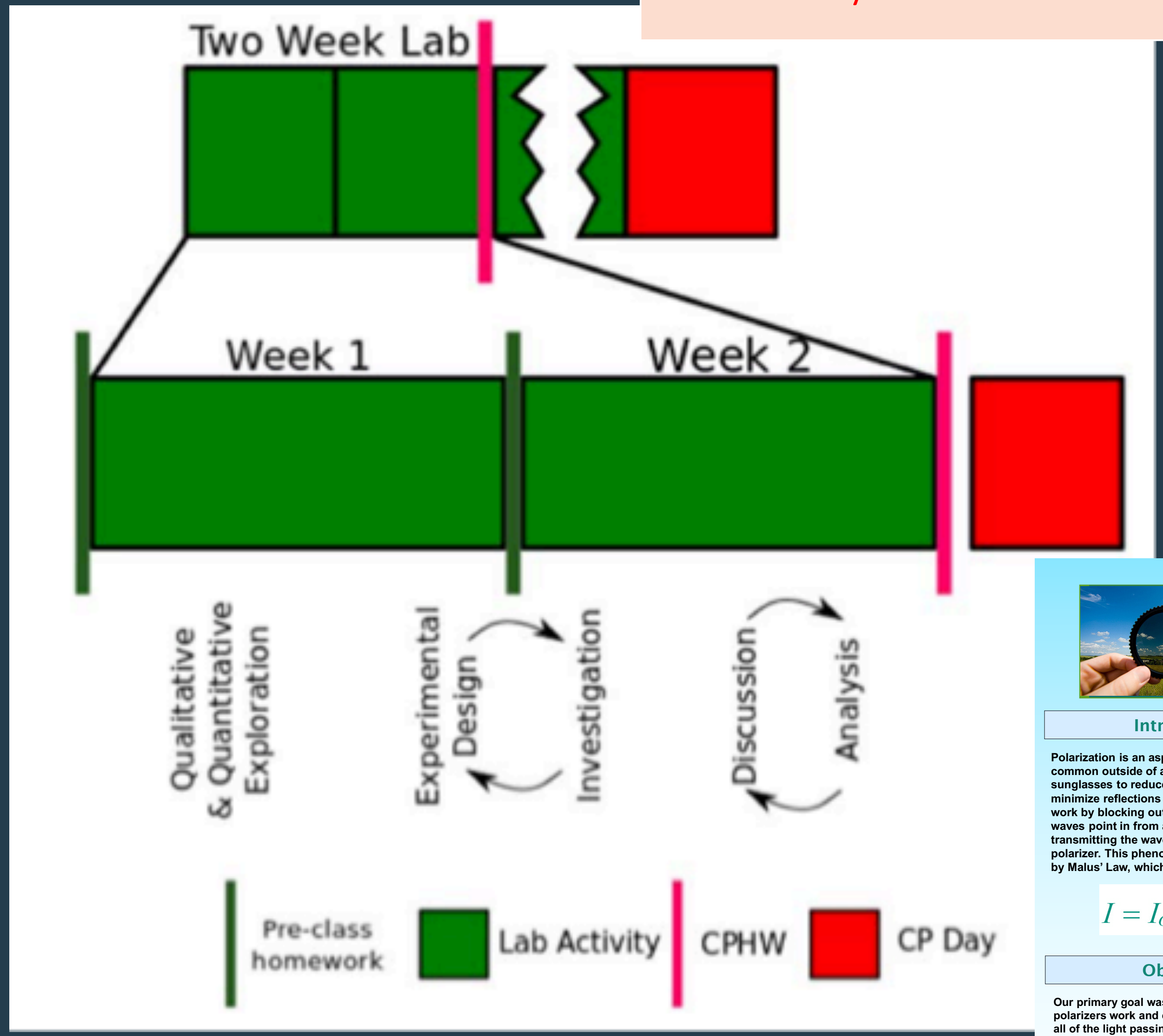


Irving, Obsniuk, & Caballero, EJP (2017)
Pawlak, Irving, & Caballero, Phys. Rev. PER (2020)
Irving, McPadden, & Caballero Phys. Rev. PER (2020)

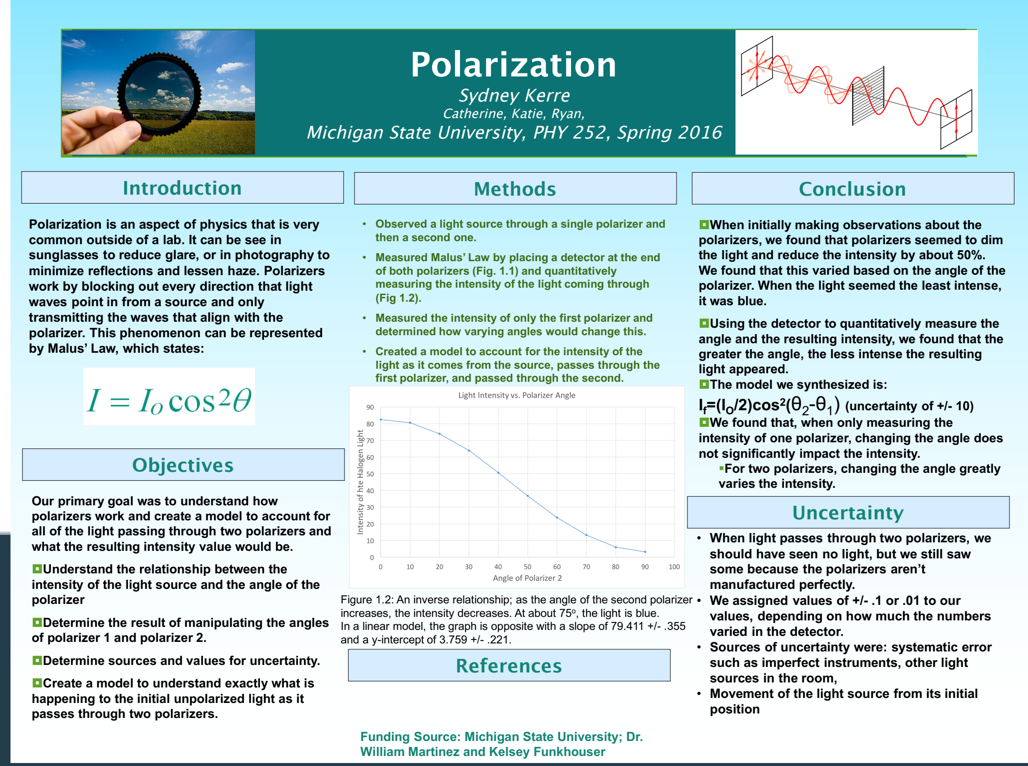
data lab

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



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