

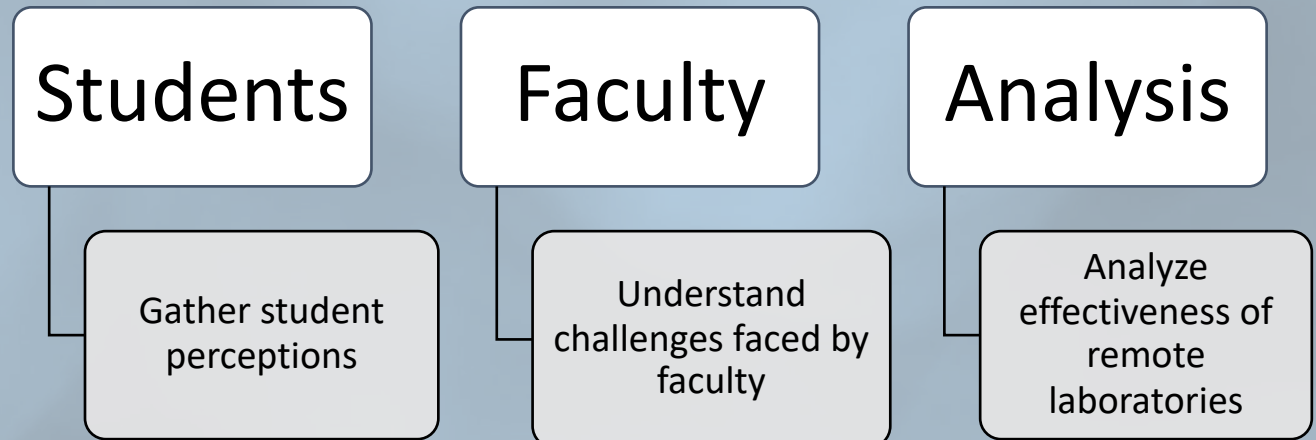


Patrick Macaulay
Zachary Newlon
Erika Wentz
Peter Zollinger

Analyzing the Effectiveness of Remote Laboratories

The COVID-19 pandemic has changed all forms of education, including labs

Online labs: How has the transition affected student learning and faculty's teaching?



Lab Courses Surveyed

Chemistry

- CH 1020

Physics

- PH 1120
- PH 1140

Engineering

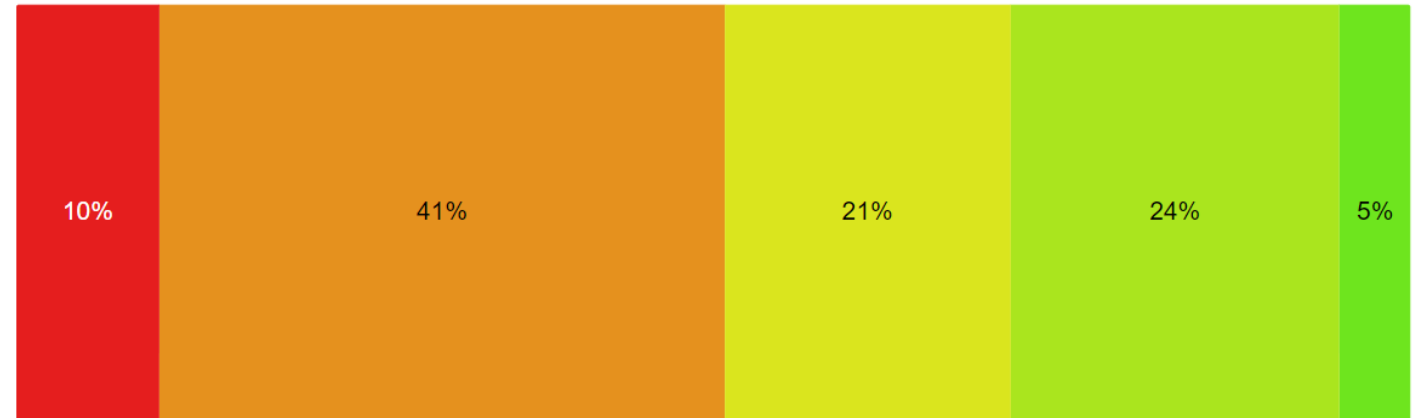
- ME 1800
- ECE 2010
- BME 3111
- ME 3902

Students have a negative opinion of remote learning

n = 195

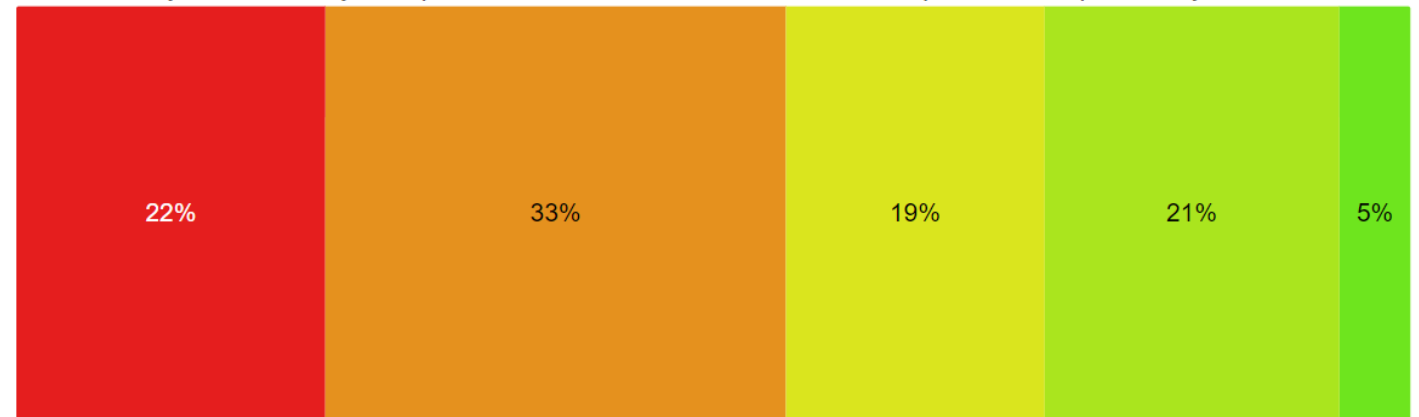
Students have stronger negative opinions of labs

How would you describe your opinion of the transition to remote learning in general?



● Extremely Negative ● Somewhat Negative ● Neutral ● Somewhat Positive ● Extremely Positive

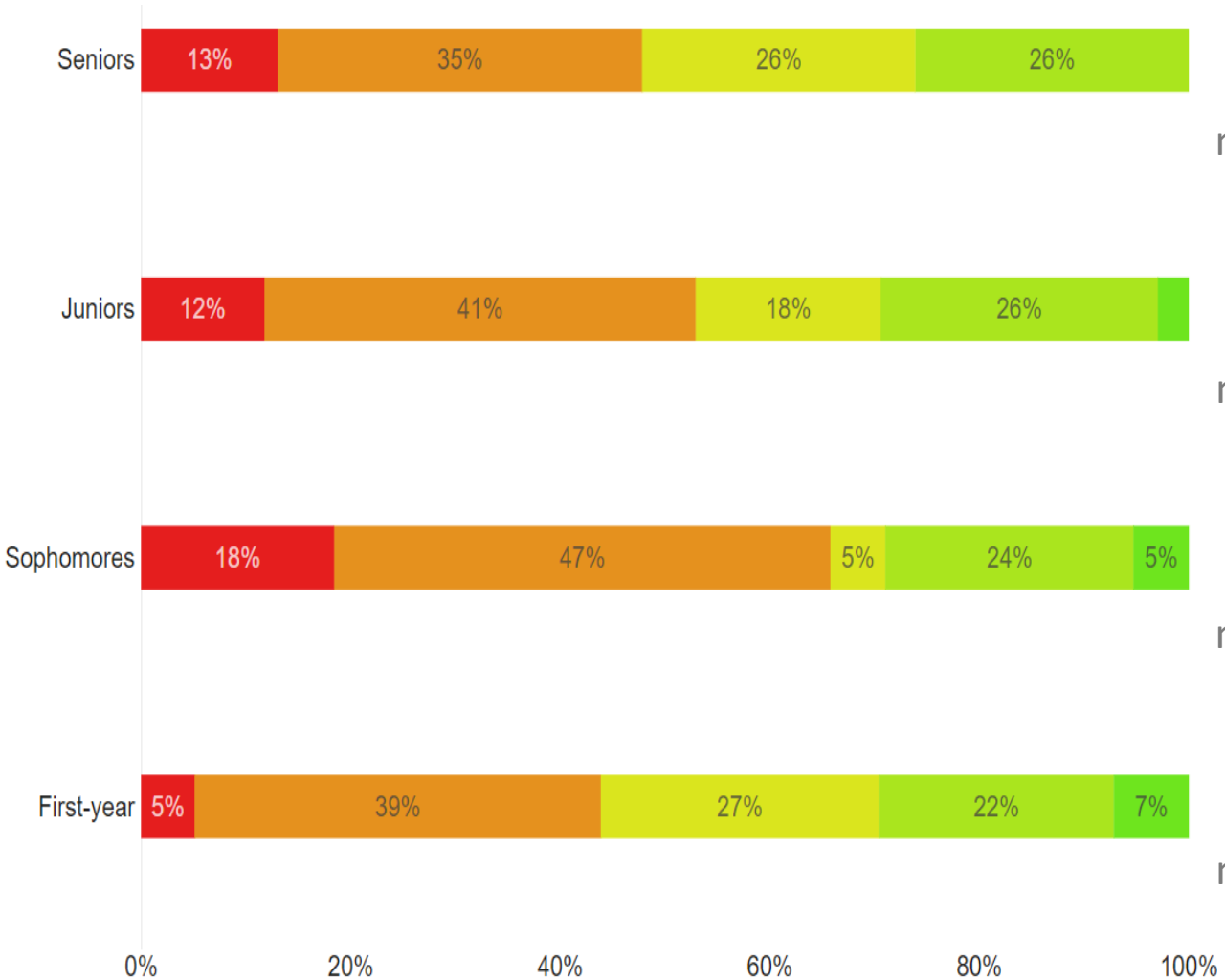
How would you describe your opinion of the transition to remote lab experiences, specifically?



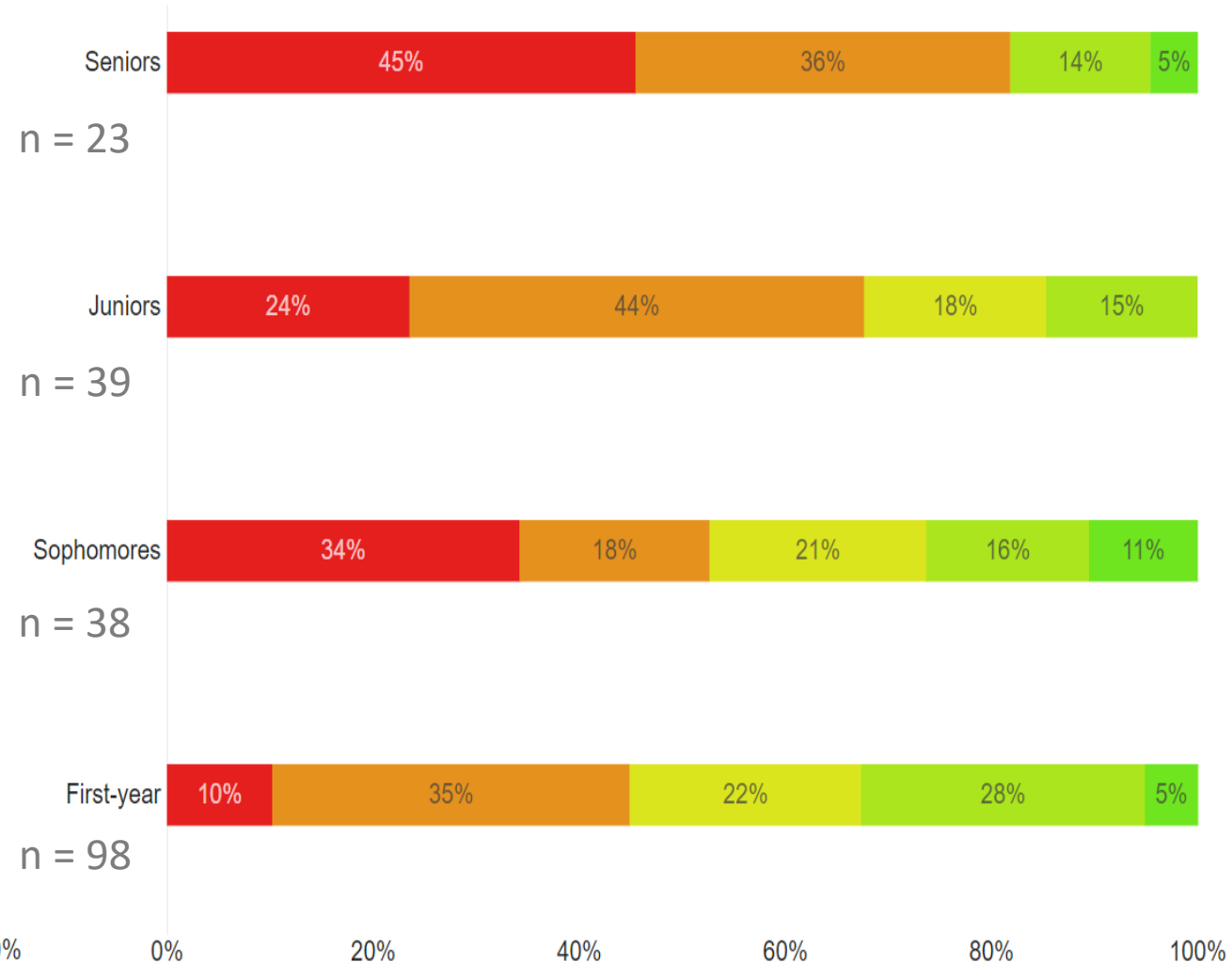
● Extremely Negative ● Somewhat Negative ● Neutral ● Somewhat Positive ● Extremely Positive

Student Experience by Year

Online Classes in General



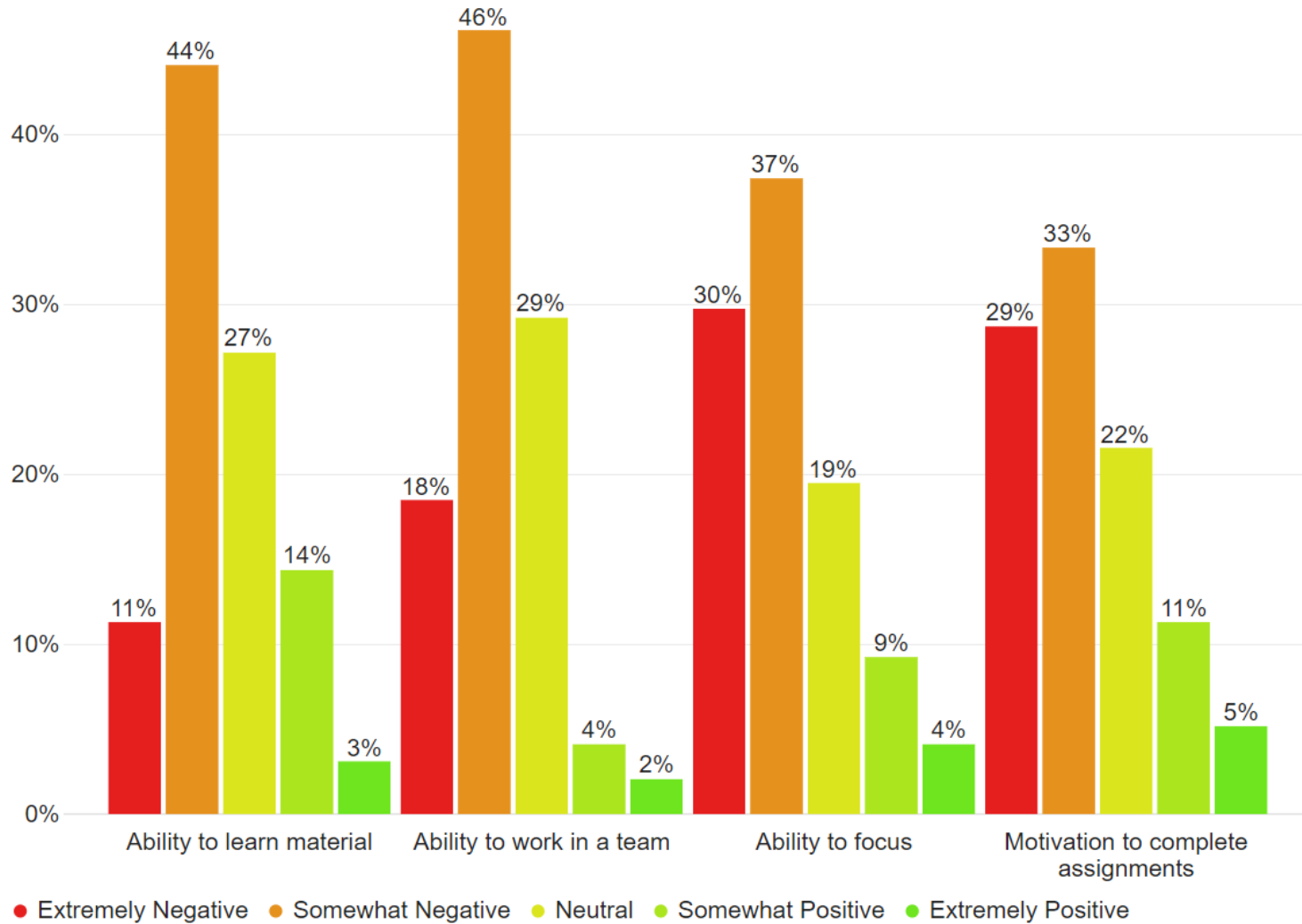
Remote Labs Specifically



● Extremely Negative ● Somewhat Negative ● Neutral ● Somewhat Positive ● Extremely Positive

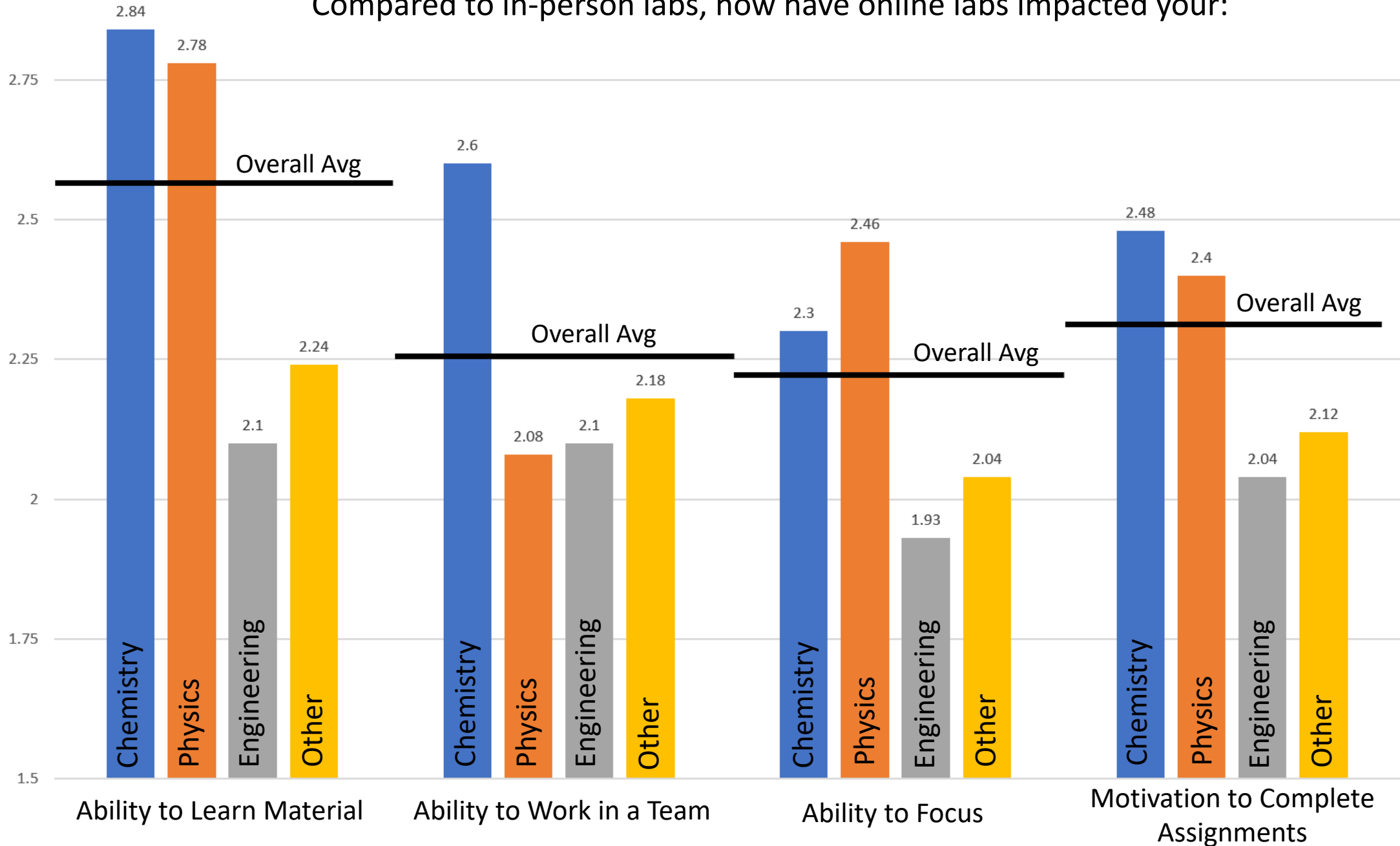
● Extremely Negative ● Somewhat Negative ● Neutral ● Somewhat Positive ● Extremely Positive

Compared to in person labs, how have online labs affected your:



Students struggle in online environments

Compared to in-person labs, how have online labs impacted your:



Student Takeaways



More time to develop understanding of concepts

Procedures are more clear

Online simulations allowed labs to still have an in-person feel

No in-person help

Labs take more time

Difficult to communicate

Difficult to stay on top of assignments

“I think that the online labs get the job done...but they just can't compare to being able to physically interact with materials”

Student Biomedical Engineering '23

Physics lab

Handwritten physics notes and diagrams:

- $E = \frac{1}{2} MgL \theta_0^2$; $\theta_0^2 = \frac{2E}{MgL}$
- $\frac{d\theta}{dt} = \left(\frac{g}{L}\right)^{1/2} (\theta_0^2 - \theta^2)^{1/2}$
- $\frac{d\theta}{(\theta_0^2 - \theta^2)^{1/2}} = \left(\frac{g}{L}\right)^{1/2} dt$
- $\int_{\theta_0}^{\theta} \frac{d\theta}{(\theta_0^2 - \theta^2)^{1/2}} = \left(\frac{g}{L}\right)^{1/2} t$
- $\int_{\theta_0}^{\theta} \frac{d\theta}{(\theta_0^2 - \theta^2)^{1/2}} = \left[\text{Arccsin} \left(\frac{\theta}{\theta_0} \right) \right]_{\theta_0}^{\theta} = \text{Arccsin} \left(\frac{\theta}{\theta_0} \right) - \text{Arccsin} \left(\frac{\theta_0}{\theta_0} \right)$
- $\left(\frac{g}{L}\right)^{1/2} t = \text{Arccsin} \left(\frac{\theta}{\theta_0} \right) - \text{Arccsin} \left(\frac{\theta_0}{\theta_0} \right)$
- $\theta = \theta_0 \sin \left(\left(\frac{g}{L}\right)^{1/2} t \right)$
- $\frac{d^2 r}{dt^2} = \frac{d^2 r}{d\phi^2} \left(\frac{\Sigma}{\rho r^2}\right)^2 + \frac{dr}{d\phi} \frac{\Sigma}{\rho} \frac{d}{dt} \left(\frac{1}{r^2}\right)$
- $\frac{d^2 r}{d\phi^2} = \frac{d^2 r}{d\phi^2} \left(\frac{\Sigma}{\rho r^2}\right) - \frac{2}{r^3} \frac{\Sigma}{\rho} \left(\frac{dr}{d\phi}\right)^2 \frac{\Sigma}{\rho r^2}$
- $W(\phi) = \frac{1}{r(\phi)}$ $\frac{dW}{d\phi} = -\frac{1}{r^2} \frac{dr}{d\phi}$; $\frac{d^2 W}{d\phi^2} = -\frac{1}{r^3} \frac{d^2 r}{d\phi^2}$
- $\frac{d^2 r}{dt^2} = -\frac{1}{r^2} \left(\frac{\Sigma}{\rho}\right)^2 \frac{d^2 W}{d\phi^2} - \frac{W^2 \Sigma^2}{\rho}$
- $\frac{d^2 r}{dt^2} = -\frac{GM_1 M_2}{r^2} + \frac{W^2 \Sigma^2}{\rho} \frac{d^2 W}{d\phi^2} - W^2 \frac{\Sigma^2}{\rho}$
- $x^2 + y^2 + z^2 = c^2 t^2$ $\beta = \frac{v}{c}$
- $x' = \frac{x - vt}{(1 - v^2/c^2)^{1/2}}$ $t' = \frac{t - (v/c^2)x}{(1 - v^2/c^2)^{1/2}}$
- $E = \frac{Mc^2}{(1 - v^2/c^2)^{1/2}}$ $E = Mc^2 + \frac{1}{2} Mv^2$
- $E^2 = p^2 c^2 + M^2 c^4$ $E = (p^2 c^2 + M^2 c^4)^{1/2}$
- $= Mc^2 \left[1 + \left(\frac{p^2}{M^2 c^2}\right) \right]^{1/2}$ $\sum_{i=1}^n E_i = c^2 \sum_{i=1}^n \epsilon_i$
- $\Delta t' = \Delta t \sqrt{1 - \frac{v^2}{c^2}}$ $\epsilon = \epsilon_0 \left(\frac{1}{1 - v^2/c^2}\right)^{1/2}$
- $E_0 = E + \frac{1}{2} \epsilon + \frac{1}{2} \epsilon_0$
- $\Delta p_{rel} = \left(1 - \frac{v^2}{c^2}\right)^{1/2} \frac{\Delta p_{cl}}{1/\gamma} = \left(1 - \frac{v^2}{c^2}\right)^{1/2} \frac{\Delta p_{cl}}{\Delta t}$ $\frac{dp_{rel}}{dt} = \frac{dp_{cl}}{dt}$
- Diagram of a pendulum with forces F_1 , F_2 , and F_3 and length $2a$.
- Diagram of a spring-mass system with mass M and spring constant k .
- Diagram of a circuit with a battery and a resistor.
- Graphs of $\sin(\omega t)$ and $\cos(\omega t)$ waves.
- Equations for simple harmonic motion: $\ddot{x} + \frac{g}{L} \sin \theta = 0$, $F_x = -Cx$, $M\ddot{x} = -Cx$, $\ddot{x} + \frac{C}{M}x = 0$.
- Equations for wave motion: $\ddot{x} = -\omega^2 A \sin(\omega t + \phi)$, $\ddot{x} + \omega_0^2 x = 0 \rightarrow \omega_0 = \left(\frac{C}{M}\right)^{1/2}$, $v_0 = \omega_0 A \cos \phi$.
- Equation for energy: $K = \frac{1}{2} M \dot{x}^2 = \frac{1}{2} M \left[\omega_0 A \cos(\omega_0 t + \phi) \right]^2$.
- Equation for average kinetic energy: $\langle K \rangle = \frac{1}{T} \int_0^T K dt = \frac{1}{2} M \omega_0^2 A^2 \int_0^T \frac{\cos^2(\omega_0 t + \phi)}{2\pi/\omega_0} dt$.
- Equation for average energy: $E = \langle K \rangle = \langle U \rangle = \frac{1}{2} M \omega_0^2 A^2$.

Instructor Takeaways



More time to review concepts

Higher quality lab reports

Online simulations are safe for students and equipment

Lacking in-person connection

Difficult to communicate

Missing experimental process





David Mavor
Chemistry Professor

“This is extremely stressful for absolutely everyone [and I am] trying to be accommodating to all of that.”



Rudra Kafle

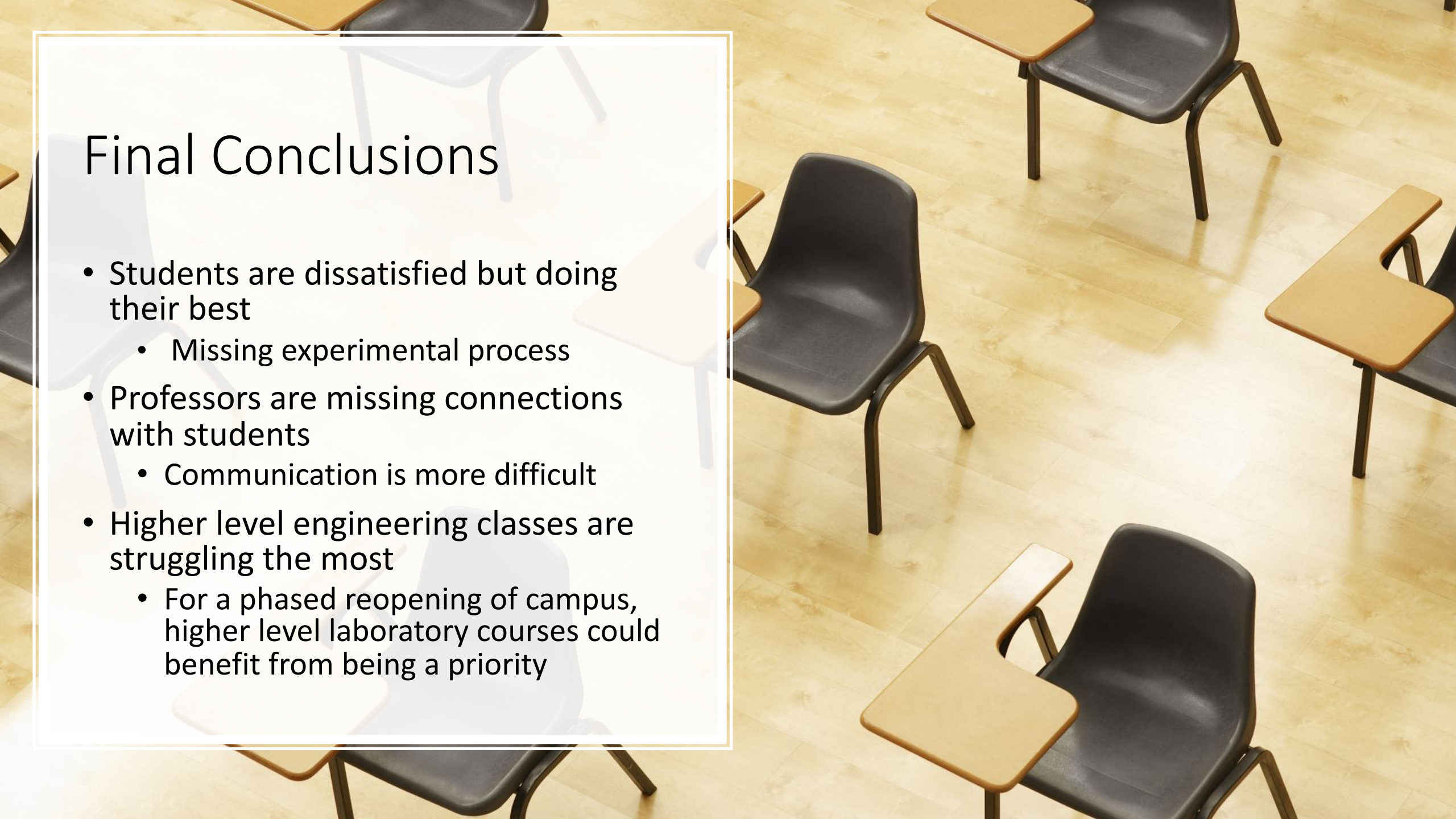
Physics Professor

Week 4 of online classes

“When the students are in my studio class, after one or two weeks, I know names of all my 72 students in the class...I know only maybe five or ten names by today.”

Final Conclusions

- Students are dissatisfied but doing their best
 - Missing experimental process
- Professors are missing connections with students
 - Communication is more difficult
- Higher level engineering classes are struggling the most
 - For a phased reopening of campus, higher level laboratory courses could benefit from being a priority



Acknowledgments

Thank you to all the instructors who worked with us to get the survey out to students.

Special thank you to those professors who took the time out of their days to speak with us about their experiences.

Thank you to our advisors, Peter Hansen and Bruce Bursten, whose guidance made this project possible.

The background is a dark gray gradient. It features several overlapping circles of varying sizes and opacities. Some circles are solid, while others are dotted. The text is centered in the middle of the slide.

Thank you

Questions?