A Holistic Approach to Design of a Mathematics Course that Supports Student Motivation and Improves Academic Success

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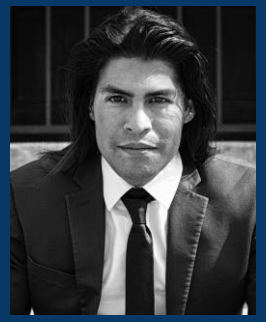
A collaborative project between a four-year university and two community colleges



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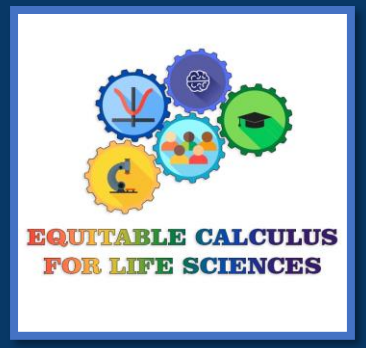
EQUITABLE CALCULUS FOR LIFE SCIENCES

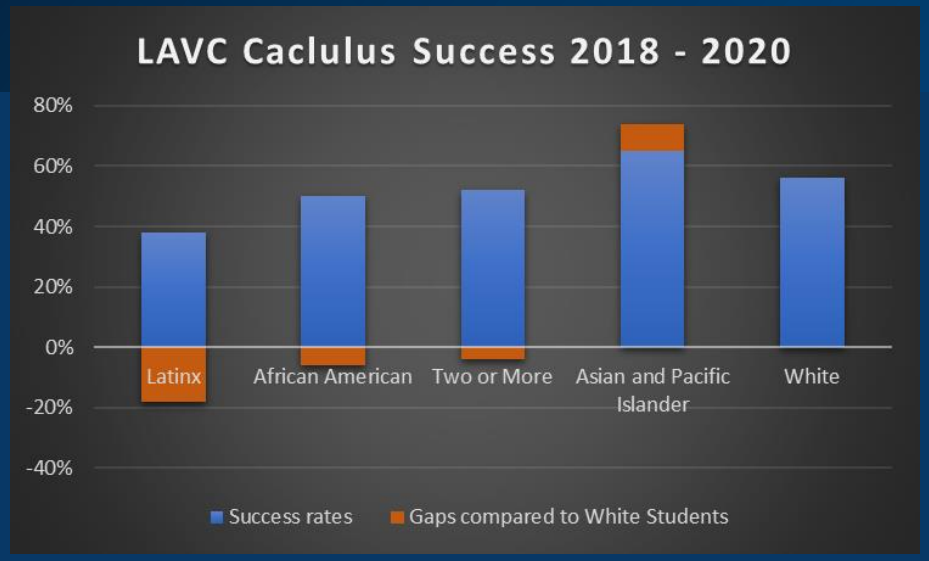
www.equitablecalculus.org

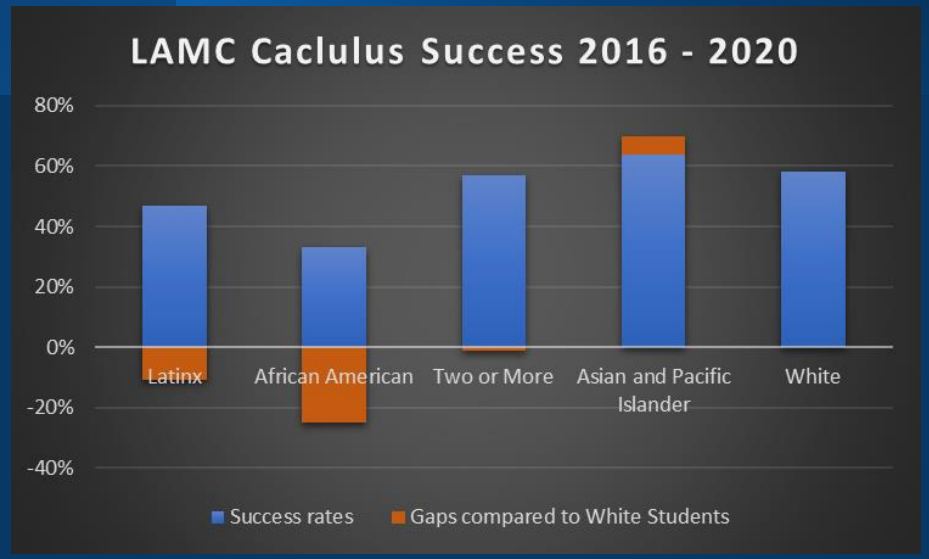
Agenda

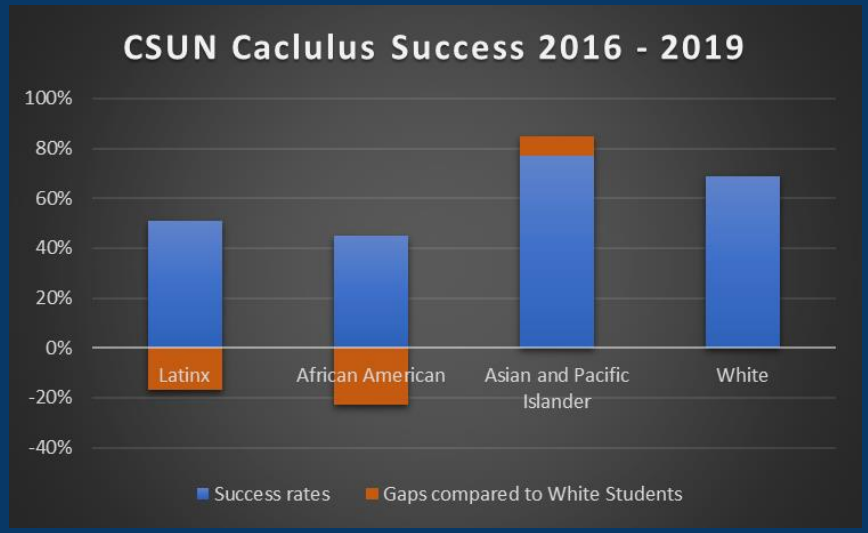
- Introduction to the Equitable Calculus for Life Sciences
- Overview of the re-designed Calculus for Life Sciences Curriculum
- A case for contextualization
- Utility-value interventions
- Gamification techniques
- Discussions and Questions



Towards Closing Equity Gaps in Calculus







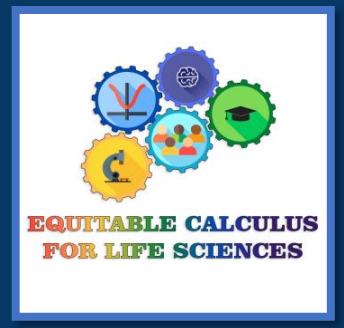
Project Overview

Faculty professional development to foster culture change

- 9 Faculty coached to teach the course
- 8 Faculty evaluated new curriculum
- 3 CRP/Antiracist workshops
- 2 Utility value intervention workshops
- 12 Student assistants trained

Calculus for Life Sciences Sequence at LACCD

- Math 247/248
- 5 units
- Articulated to UC and CSU
- Videos, tutorials, active learning worksheets
- Available on Canvas Commons



Culturally responsive, pedagogy

- Active learning
- Flipped classroom
- Contextualization
- Mitigating pre-requisites by using technology/AI

Student motivation

- Contextualization
- Utility value interventions
- Gamification

Mentorship

- Peer mentorship
- Campus Visits
- Summer and Winter Institutes

Curriculum

- Available on Canvas Commons: search for “Calculus for Life Sciences”
- Topics encompass a “traditional” calculus for life sciences curriculum, e.g. Steward’s Biocalculus
- Deliver flipped or hybrid
- Each topic features
  - Introduction linking the topic to an application
  - short, 8-15 minute video, H5P interactions added
  - pre-class quiz, HW sets on MyOpenMath
  - a contextualized worksheets for 30-45 min student group work
- Articulated to 8 UCs and 13 CSUs (all)

Articulation of Math 247/248 Sequence

University of California	**California State University**	
UC Berkeley	CSU Long Beach	California Polytechnic University, Humboldt
UC Irvine	CSU Bakersfield	CSU Maritime Academy
UC Los Angeles	CSU Channel Islands	CSU Northridge
UC Merced	CSU Chico	San Francisco State University
UC Riverside	CSU Dominguez Hills	San Jose State University
UC San Diego	CSU East Bay	
UC Santa Barbara	CSU Fresno	
UC Santa Cruz	CSU Fullerton	

Motivation

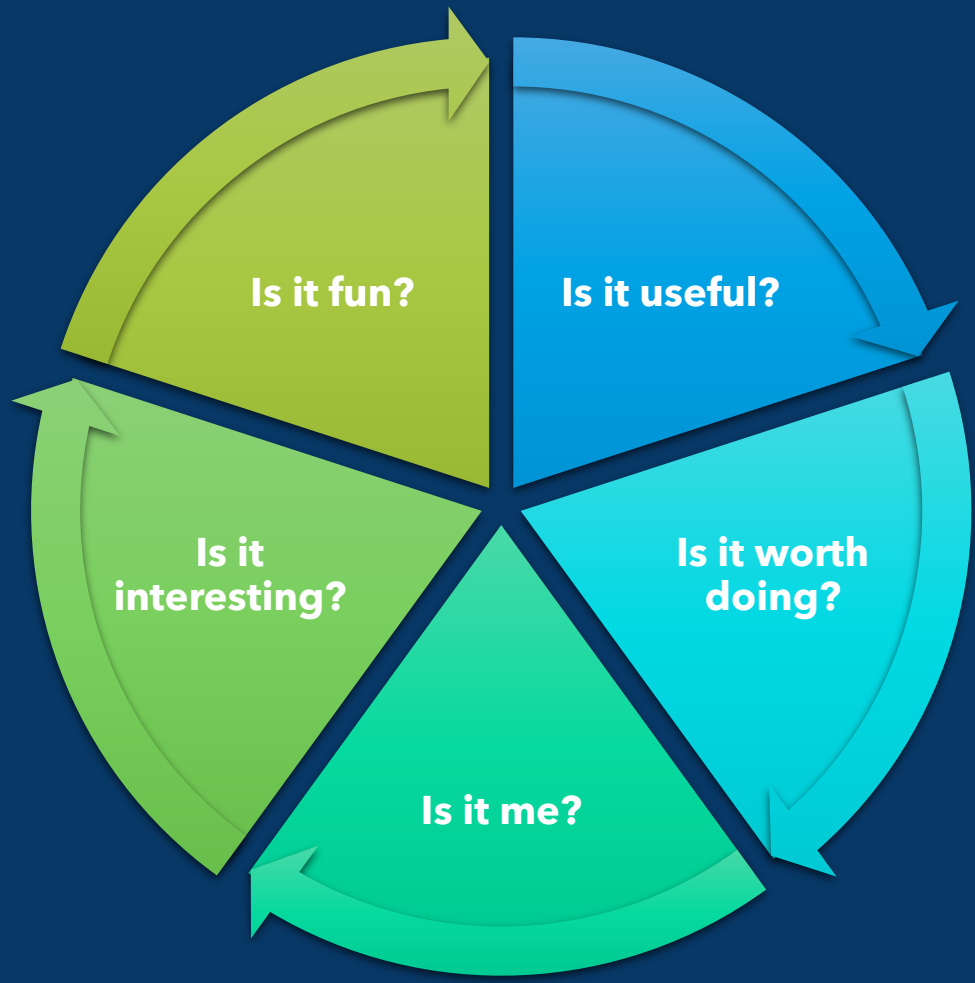
- The driving force, the energy behind goal-directed action

- What gives you energy?
- What barriers get in the way?

- NOT personality

Student Motivation

What factors go into a student's decision to engage?



What can instructors do to foster the engagement?

Contextualization of Math Curriculum in Service Courses

- Present math topics in context of applications to problems relevant to student majors
- Students carry passion for their subjects, not math
- Consider putting students subject first (it will require work)

Select a Problem that is Contextualized

Determine location and value of the absolute extreme values of $f(x)$ on the given interval, is they exist.
$f(x) = |3 - x|$, on $[2, 5]$.

- Is it useful?
- Is it interesting?
- Is it me?
- What will it cost me?

Social animals that live in groups can spend less time scanning for predators than solitary individuals. However, they waste time fighting with the other group members over the available food. There is some group size at which the net benefit is greatest because the animals spend the least time on these unproductive activities – and thus can spend time on feeding, mating,
etc.

Assume that for a group of size x, the fraction of time spent scanning for predators is

$$S(x) = \frac{A}{x+1}$$

and the fraction of time spent fighting with other animals over food is

$$F(x) = B(x+1)^2$$

where A, B are constants. Find the size of the group for which the total time wasted on scanning and fighting is smallest.

Active Learning Contextualized Worksheet

Developed by Humberto Raya Mendoza, LAVC. Topic: Chain Rule. Title: Sunny Pacoima, California.

Day light is the amount of time between sun rise and sun set. In Pacoima, California the amount of daylight through the year can be modeled by the sinusoidal function

$$D(t) = 2.675\cos\left(\frac{2\pi}{365}t\right) + 12.175$$

where t is in days after June 21st and $D(t)$ is in hours of day light. Use this model to answer the following questions:

A. Compute the day light on June 30th.
B. Compute $D'(t)$ and interpret $D'(9)$.
C. A solar panel generates a daily power W in watts according to the equation $W(t) = 300[D(t)]^{5/6}$.
    a) Compute the watts are generated on June 30th?
    b) If average American household consumes 29,130 Watts of electricity per day, do the solar panels provide enough energy to power a household?
    c) Compute W'(t)

Utility-Value Interventions

Developed by Dr. Stacy Priniski, Temple University

- Evidence-based activities to help students see personal relevance and usefulness of course topics.
  - If it is worth it, it is more interesting, it gives sense of purpose
  - If you can apply it, you can understand it.

Contextualized → Culturally Relevant → Personalized

Equity Considerations

- If we make examples that are relevant to the “average student” who is left out?
  - a “standard” story problem about daily vs. weekly bus passes: students whose parents had white-collar jobs answered the question differently than those whose parents worked multiple jobs and/or > five days/week
- How do we make course content relevant to students with vastly different experiences?
- What if students have different goals?
- What if applications, careers are stereotyped?

Foundational Evidence

Context	Studies	Results
High school science	Hulleman & Harackiewicz,2009	⬆ interest & grades for students with low expectancies
9th-grade math	Gaspard et al., 2015 Rosenzweiget al., 2019	⬆ interest & value ⬆ value
College psychology	Hulleman et al., 2010	⬆ interest for students with low grades
Community college math	Kosovich et al., 2019	⬆ pass rates, esp. for low-performing men
College chemistry, physics	Rosenzweig et al., 2020 Wang et al., 2020	⬆ grades, esp. for students with low grades ⬆ grades; ⬆ value for students with low value
College biology	Canning et al., 2018 Curry et al., 2019 Harackiewicz et al., 2016 Hecht et al., 2019	⬆ grades & persistence ⬆ interest & value ⬆ grades, esp. for students with low grades, FG-URM students ⬆ persistence for confident students, FG-URM students

Implementation of Interventions

Students are given three activities (<15 mins) as course assignments.

- Students are presented 5 quotes based on responses from former students, about the usefulness of calculus.

Assignment 1	Assignment 2	Assignment 3
• Rate the quotes and choose their favorite.	• Connect calculus to their own lives.	• Make additional connections and reflect on how their opinions about calculus have changed

- Responses graded on thoughtful completion.
- Control group rates calculus problems and reflects on what makes a good homework problem

Sample Quote

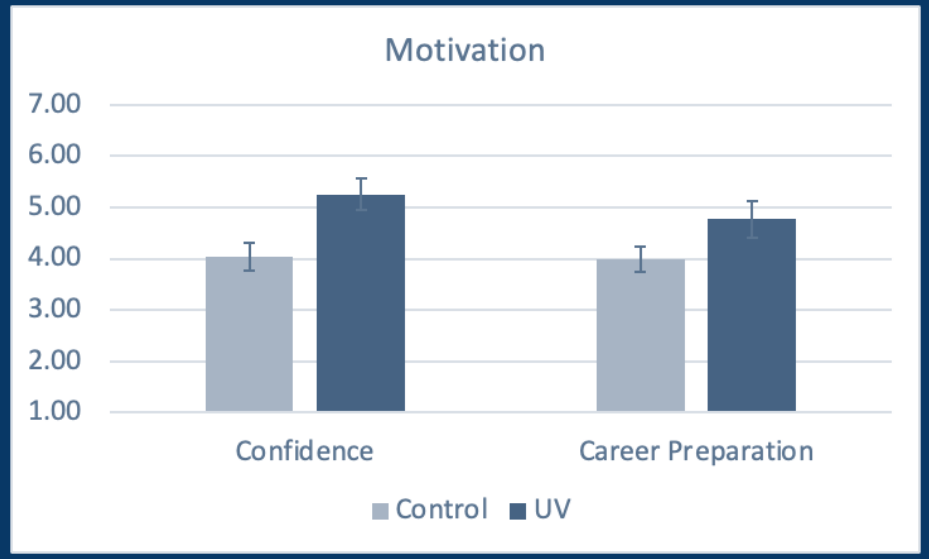
I thought calculus was pretty tough. I had to work harder in that class than most of my other classes. But the tutors helped. I also did extra practice problems online. That helped too. Over time it got easier. Now looking back I'm glad I put in all that work because calculus shows up more than I expected. There are equations for modeling enzyme reactions, for bacteria growth under the influence of different environmental features. I've seen those in my classes. And it seems like calculus can be applied to most kinds of research, including the kind of research I want to do on the gut microbiome and diet.

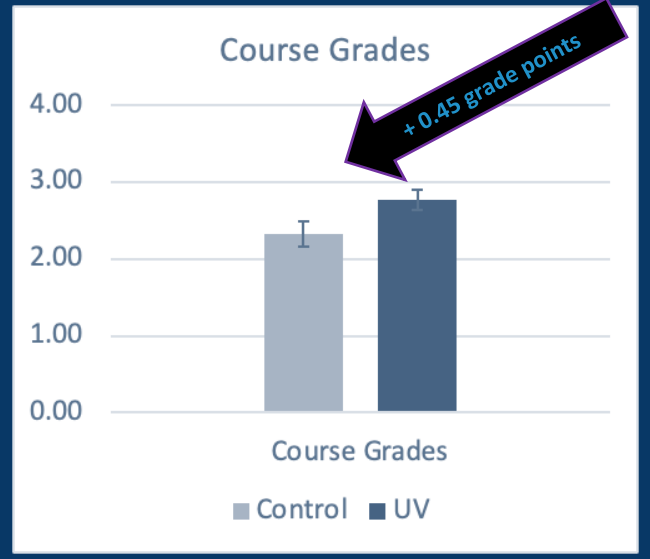
- Carmen, age 21, major: Microbiology

Assignment Responses

I don't think anyone from the beginning willingly takes calculus with the intent of enjoying it, save for the very few exceptional students who love math. After actually experiencing calculus, safe to say my perspective has changed dramatically: in every chapter we're given real-world examples, whether it be populations to red blood cell counts to finding the areas of complex shapes. Calculus may be a difficulty spike, but along with it comes multiple opportunities to realize why math actually matters in this world.

Results: Utility-Value Intervention

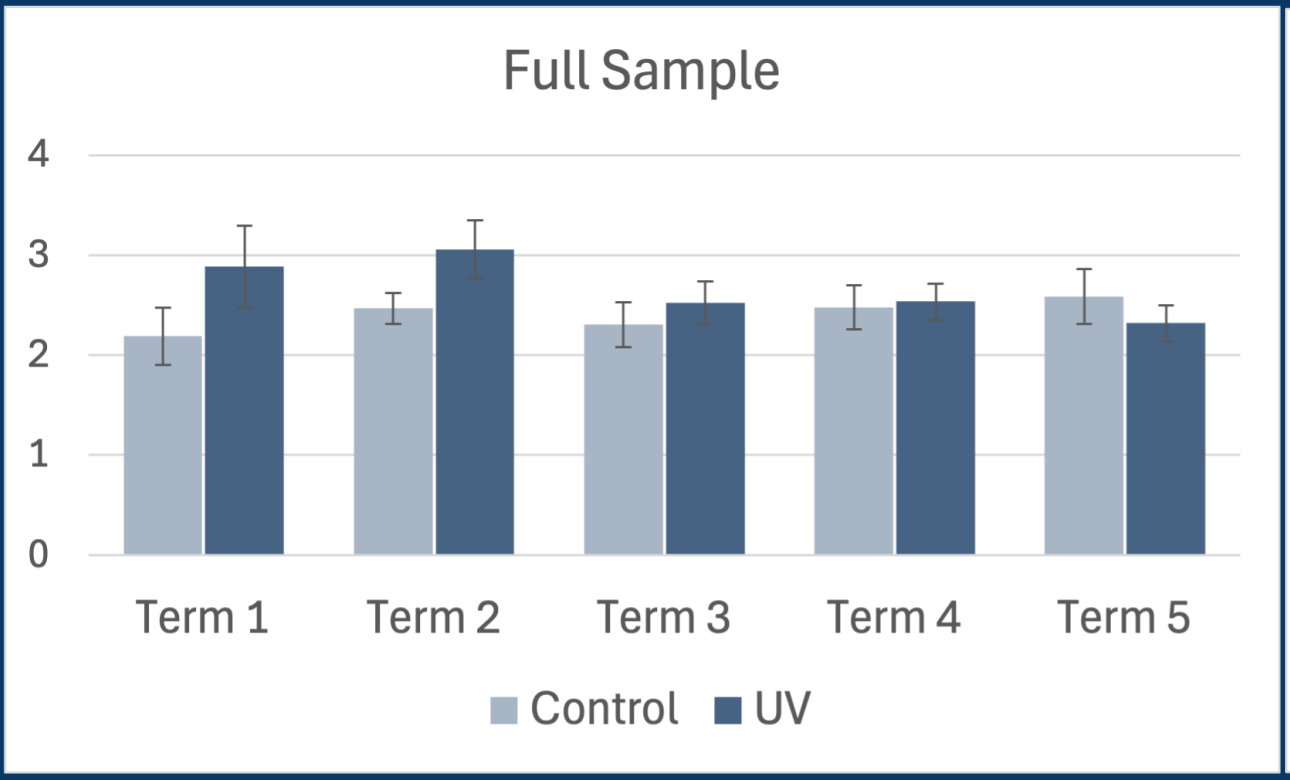


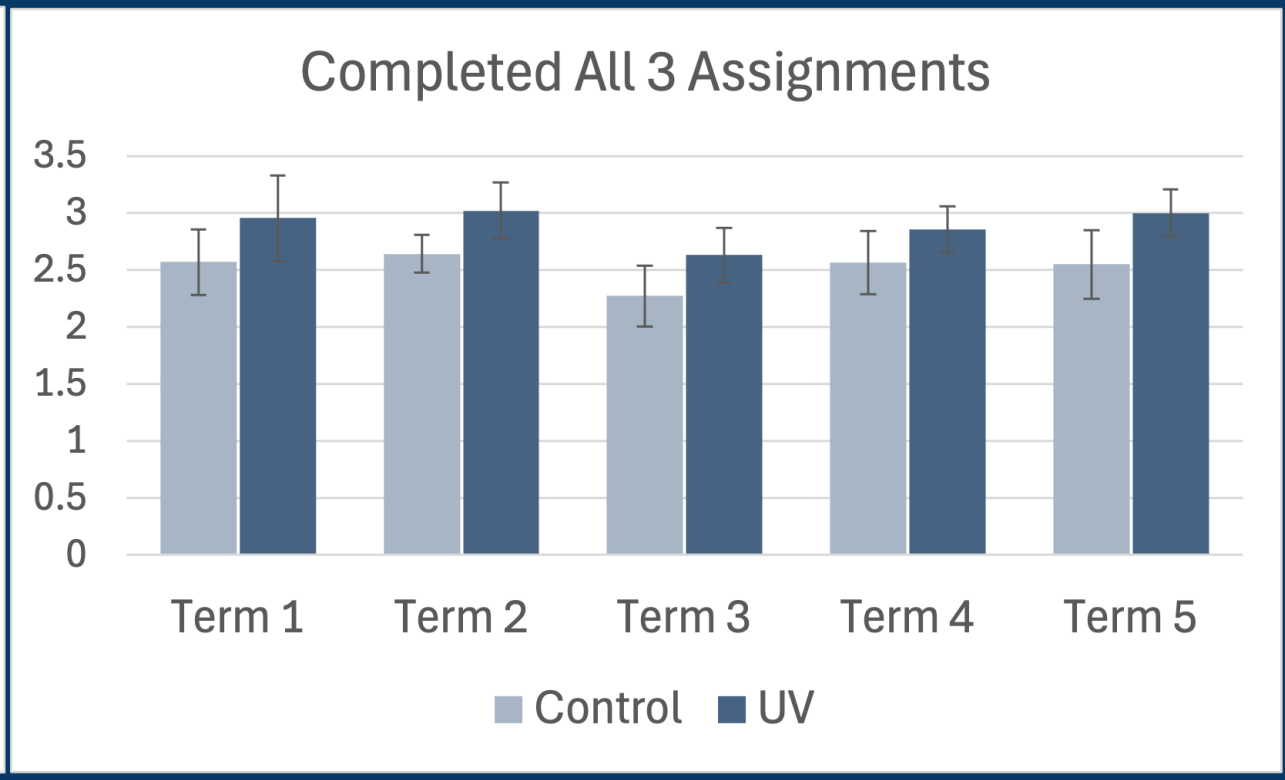


- ***Student motivation and course grades for Spring 22 – Spring 23 semesters.***

- *Values are raw means; error bars are +/- 1 standard error. Confidence and Career Preparation were measured on a 1-7 scale. Course grades were on a 4.0 scale. (110 students)*

Results: Utility-Value Intervention, cont'd





- ***Course grades for Spring 22 – Spring 24 semesters.***
- *Values are raw means; error bars are +/- 1 standard error. Course grades were on a 4.0 scale. (219 students, 153 students)*

You Can't be Serious!

Playing Games in the Classroom?!

In College?!

(Yup... We do...)

Developed by Bamdad Samii, LAMC and A.A.

Games and Learning

The **gamification** of **learning** is an **educational** approach that seeks to motivate students by using game design and game elements in **learning** environments.

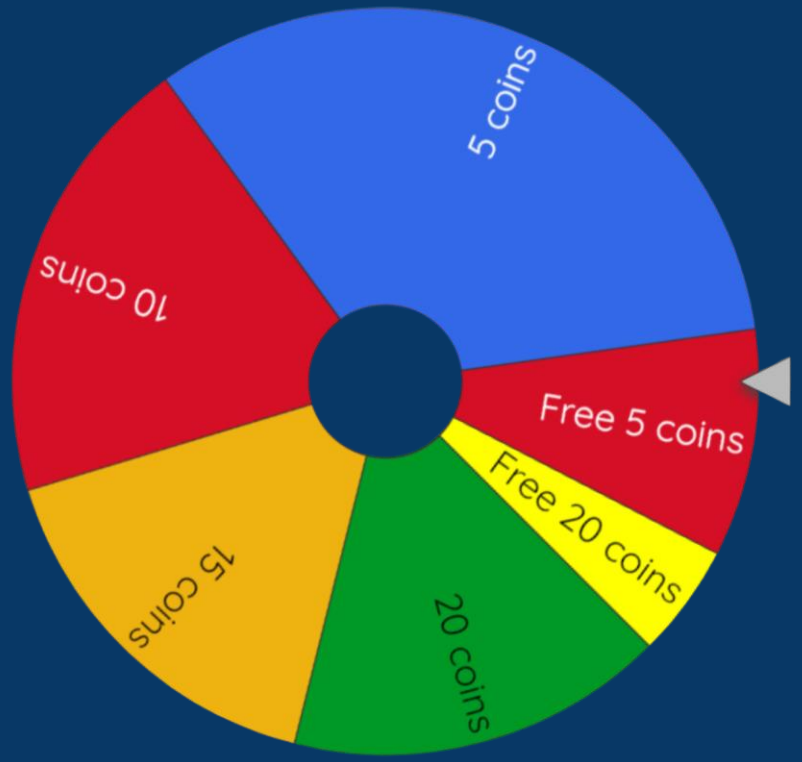
Gaming	Learning
Exploring a new world	Exploring a new subject
Quests	Learning objectives
Points and badges	Grades and awards
Social interaction: collaboration and competition	Social interaction: Groupwork
Learn from failures	Learn from failures
Time limit and stress	Deadlines and pressure

Common Gaming Strategies

Random Rewards	Point System	Challenges and Levels	Leaderboard and Badges	Quests	Role playing
• Creates Enthusiasm • Builds Persistence	• Builds motivation • Increases engagement	• Promotes critical thinking • Builds patience and problem solving	• Develops a competitive environment • Feeling of recognition	• Encourages collaboration • Teaches Information gathering	• Engagement • Creativity

Randomized Reward

Point value for completing daily quizzes are randomly determined. Includes chance for points for wrong answers.



https://wheelofnames.com/

Pros

- Encourages students to prepare
- Increases attendance

Cons

- Instructor needs to keep track

Points and Perks System

Develop a system for earning and using/spending points for course related perks of their choosing.

Time Warp – 20 coins

Go back in time 2 days and complete an assignment

Cloak of invisibility – 20 coins

This item will allow you look through your notes for 1 minute during a test without the teacher seeing you

Book of Remedies – 20 coins

This item will allow you to bring in a page of notes to your next test

Pros

- Higher motivation to complete tasks
- Personalization of assessment

Cons

- Keeping track
- Balancing appropriate perks

Points and Perks System - bonus

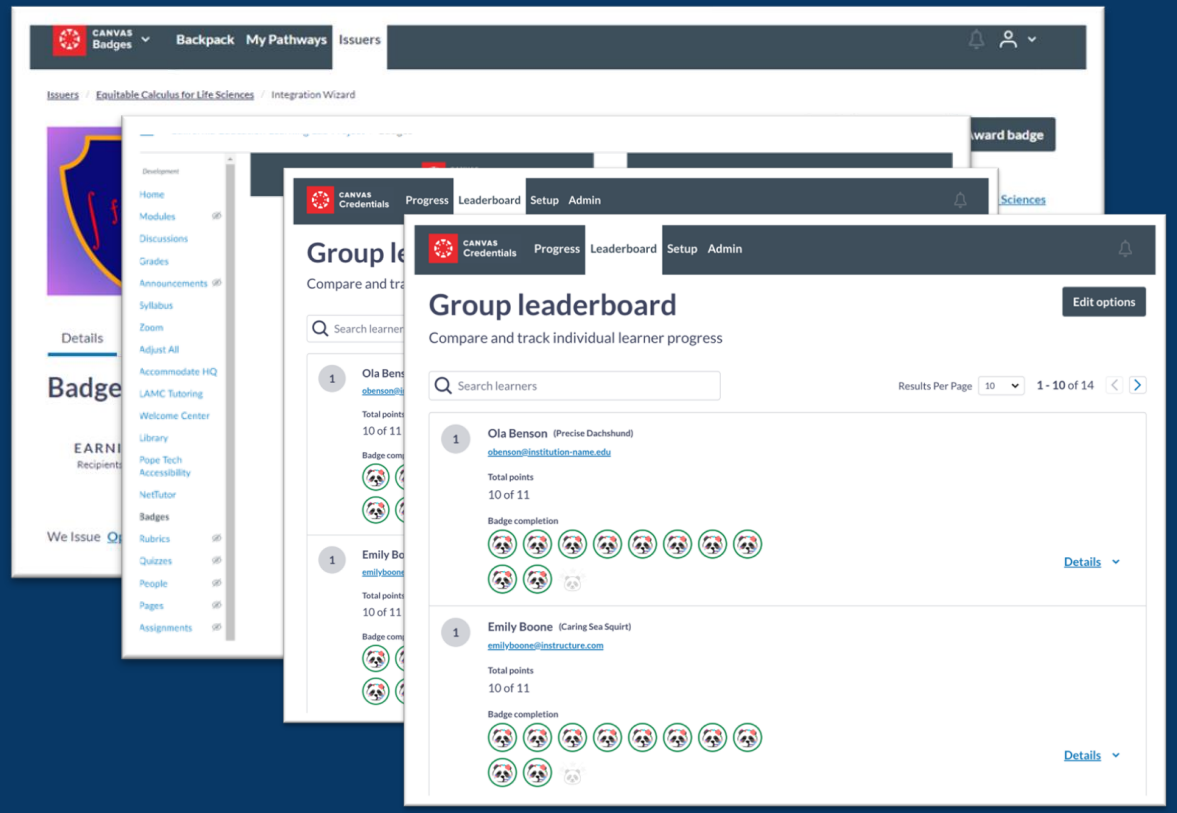
Additional gaming strategies:

- Extra points for early completion of task
- Decoy point distribution

- Parlays (Extra points for completing multiple tasks)

Leader Boards / Badges

Badgr.com Or Canvas Badges



Introduce opportunities to compete and be recognized

Pros

- Creates sense of achievement
- Sets goals
- Pre-built into Canvas LMS

Cons

- Demotivation for Lower-Ranked Students

Game as Part of the Course Assessment

Math Hunger Games

Introduce activity where student teams compete to earn credit in the course

Pros

- Determination of the winner is completely peer based
- Students collaborate by forming teams
- Greatly facilitates creative work and critical thinking
- Only need to do better than the opposing team
- Done outside of direct instruction time

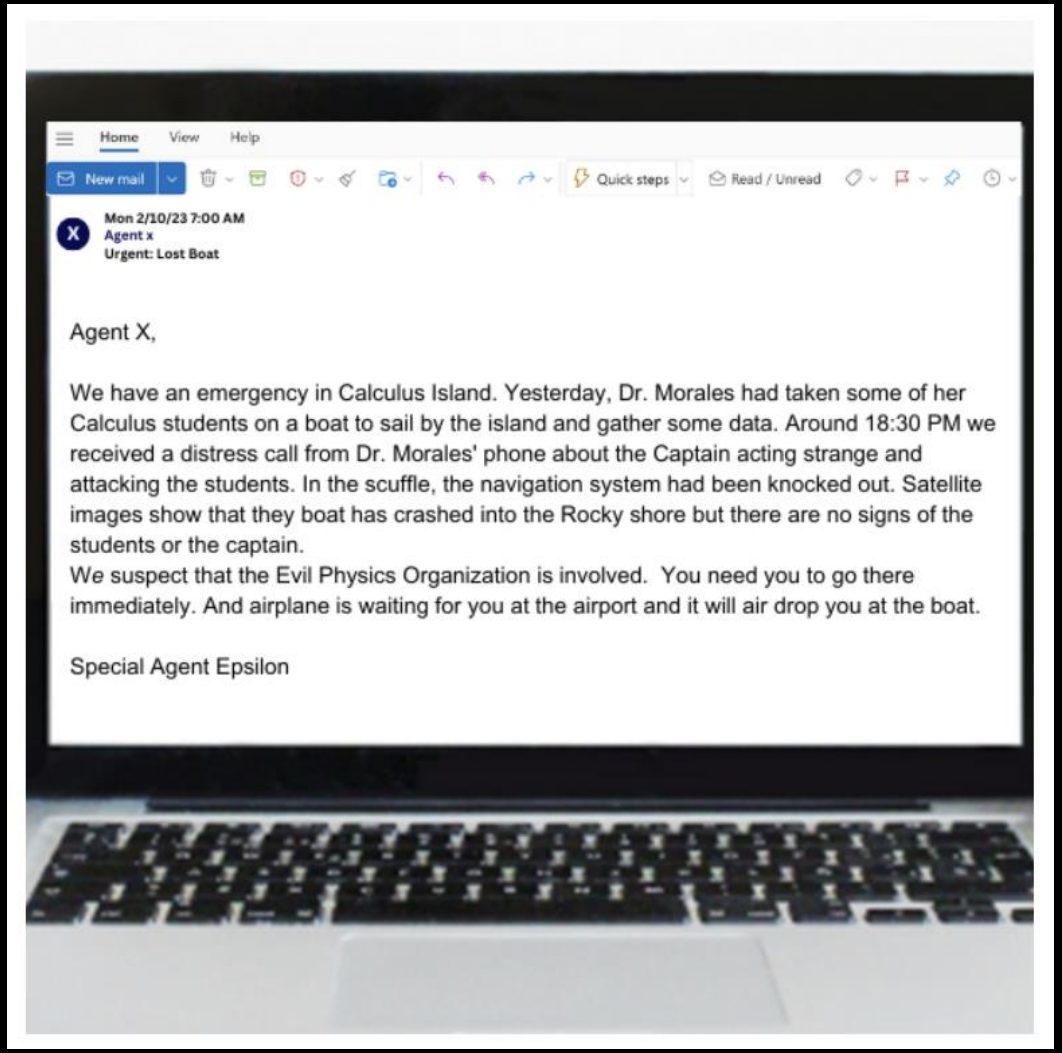
Cons

- Additional work for instructor to moderate the game
- First year students have difficulties function as teams

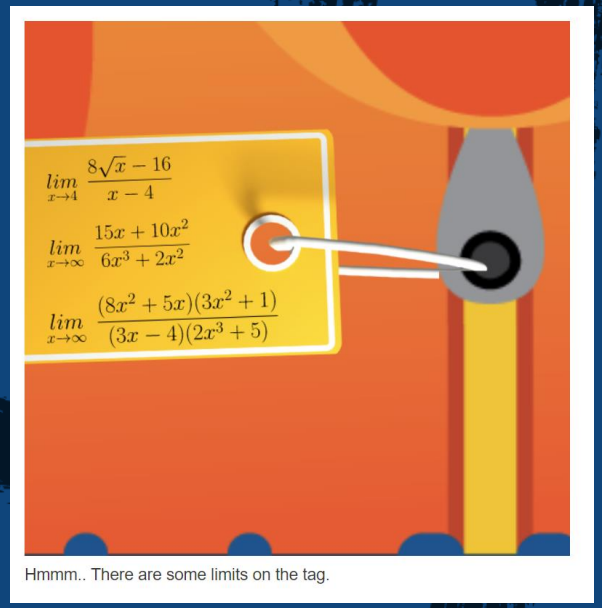
ROLE PLAYING

Games are created using Canva images and H5P platform in Libretexts Studio.

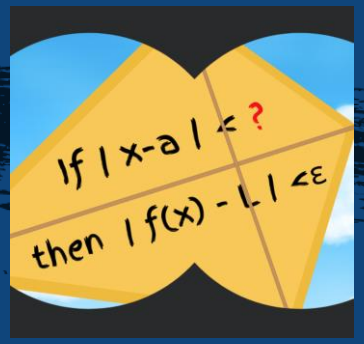
- Calculus Island – The Resue
- Return to Calculus Island – The Serum



Calculus Island – The Resue



Hmmm.. There are some limits on the tag.



Complete games:

A.I. Gamification Helper

How do I get started

- https://www.playlab.ai/project/clygeop8w09cnxtkp2x3c08x0

Improvement in Retention and Matriculation Rates

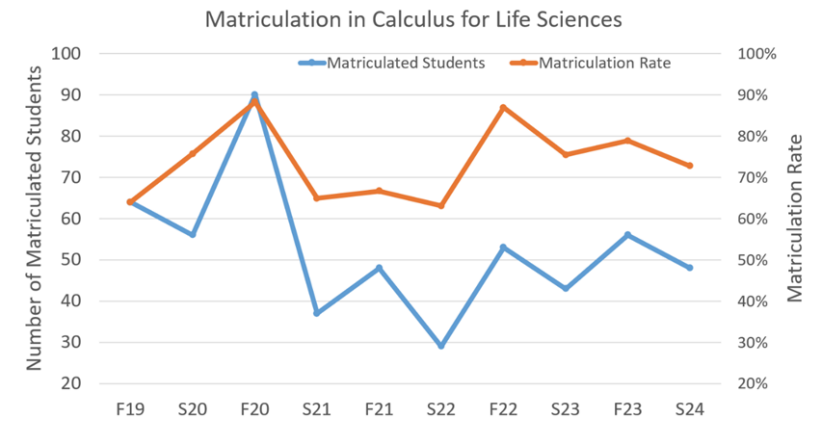


Figure 1. Historical matriculation data for Calculus for Life Sciences at CSUN.

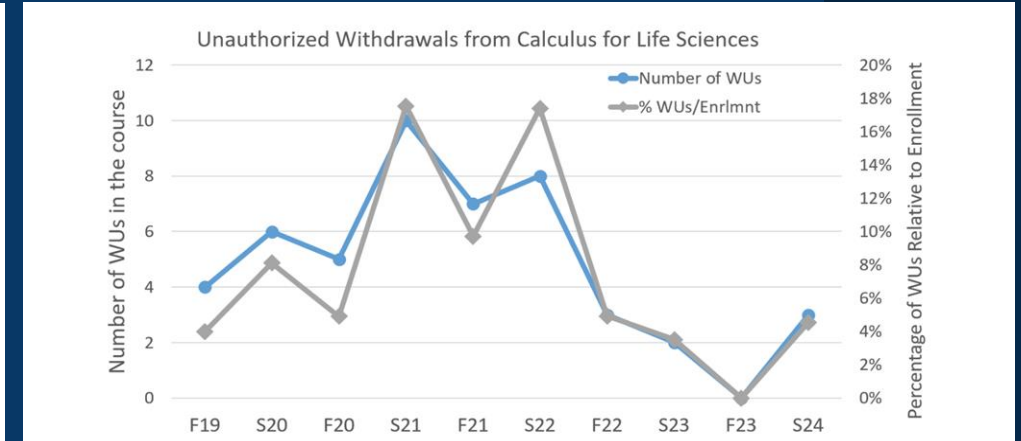


Figure 2. Historical data on unauthorized course withdrawals from Calculus for Life Sciences at CSUN.

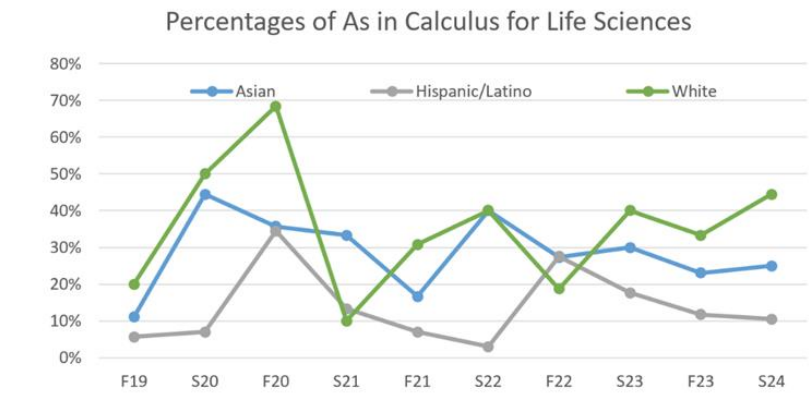


Figure 6. Shares of As in Calculus for Life Sciences course by ethnicity. Rates are computed relative to sizes of student ethnic groups.

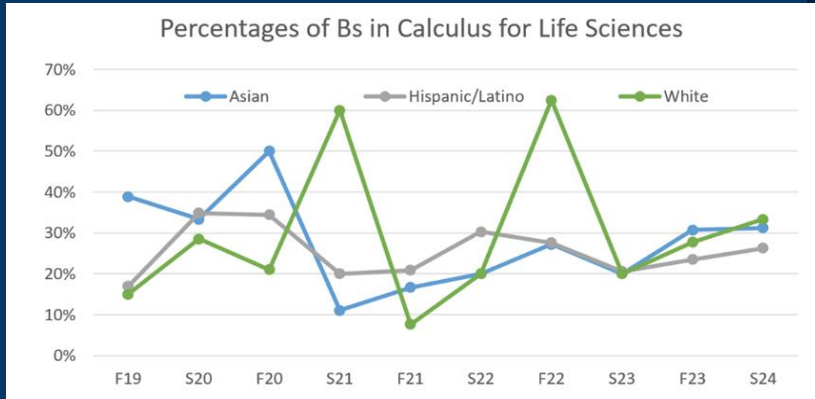


Figure 8. Shares of Bs in Calculus for Life Sciences course by ethnicity. Rates are computed relative to sizes of student ethnic groups.

Course Features

- Contextualization
- Active Learning
- UV Interventions
- Gamification (some instructors)

- Reduction in withdrawals
- Improved Matriculation

More work needs to be done to close equity achievement gap. Build better sense of belonging for struggling students

Anatomy of a Set of UV Quotes

- I honestly don't think I will use calculus very many times in my life. The majority of the time we use math it's to solve a simple problem such as finding prices or discounts or tips. I might pick a job that requires lots of math, but even if I don't I guess I'm still glad I took the course. Working through calculus problems really helped me to think logically and take problems one step at a time. What is the problem? What variables will factor in? The logic applies beyond just math.

- Marissa, age 22, major: Construction Management

Authentic mix of opinions, but all skew positive

Mix of concrete and abstract, specific and general connections

Representation of various student identities, avoid stereotypes

Utility Value Intervention References

- Albrecht, J. R. & Karabenick, S. A. (2018). Relevance for Learning and Motivation in Education, The Journal of Experimental Education, 86:1, 1-10, https://doi.org/10.1080/00220973.2017.1380593
- Canning, E. A., & Harackiewicz, J. M. (2015). Teach it, don't preach it: The differential effects of directly-communicated and self-generated utility–value information. Motivation Science, 1, 47-71. https://doi.org/10.1037/mot0000015
- Canning, E. A., Harackiewicz, J. M., Priniski, S. J., Hecht, C. A., Tibbetts, Y., & Hyde, J. S. (2018). Improving performance and retention in introductory biology with a utility value intervention. Journal of Educational Psychology, 110, 834-849. https://doi.org/10.1037/edu0000244
- Curry, K. W., Spencer, D., Pesout, O., & Pigford, K. (2019). Utility value interventions in a college biology lab: The impact on motivation. Journal of Research in Science Teaching, 57, 1-21. https://doi.org/10.1002/tea.21592
- Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectations, values and academic behaviors. In J. T. Spence (Ed.), Perspective on achievement and achievement motivation (pp. 75–146). San Francisco, CA: Freeman
- Eccles, J. S., & Wigfield, A. (2000). Expectancy-value theory of achievement motivation. Contemporary Educational Psychology, 25, 68–81. https://doi.org/10.1006/ceps.1999.1015
- Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61,* 101859. https://doi.org/10.1016/j.cedpsych.2020.101859
- Gaspard, H., Dicke, A.-L., Flunger, B., Brisson, B. M., H€afner, I., Nagengast, B., & Trautwein, U. (2015). Fostering adolescents' value beliefs for mathematics with a relevance intervention in the classroom. Developmental Psychology, 51, 1226–1240. https://doi.org/10.1037/dev0000028
- Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., & Hyde, J. S. (2016). Closing achievement gaps with a utility-value intervention: Disentangling race and social class. Journal of Personality and Social Psychology, 111, 745-765. https://doi.org/10.1037/pspp0000075
- Harackiewicz, J. M., & Priniski, S. J. (2018). Improving student outcomes in higher education: The science of targeted intervention. Annual Review of Psychology, 69, 409–435. http://dx.doi.org/10.1146/annurev-psych-122216-011725
- Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing Interest and Performance With a Utility Value Intervention. Journal of Educational Psychology, 102, 880-895. https://doi.org/10.1037/a0019506

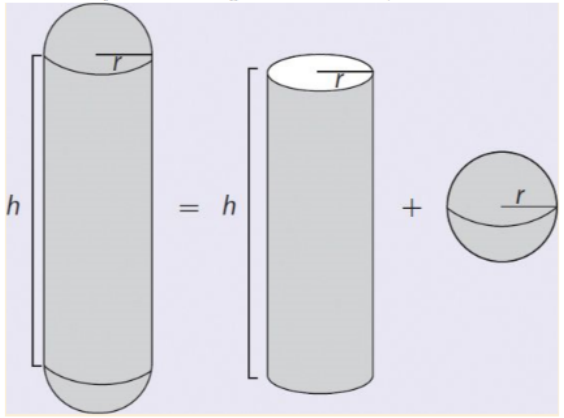
Utility Value Intervention References, cont'd

- Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. Science, 326, 1410–1412. https://doi.org/10.1126/science.1177067
- Hulleman, C. S., Kosovich, J. J., Barron, K. E., & Daniel, D. B. (2017). Making connections: Replicating and extending the utility value intervention in the classroom. Journal of Educational Psychology, 109, 387–404. https://doi.org/10.1037/edu0000146
- Hulleman C. S., Thoman D. B., Dicke A.-L., Harackiewicz J. M. (2017). The promotion and development of interest: The importance of perceived values. In P. O'Keefe & J. M. Harackiewicz (Eds.) The Science of Interest. Springer. https://doi.org/10.1007/978-3-319-55509-6_10
- Kosovich, J. J., Hulleman, C. S., Phelps, J., & Lee, M. (2019). Improving algebra success with a utility-value intervention. Journal of Developmental Education, 42, 2–10.
- Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2018). Making learning personally meaningful: A new framework for relevance research. Journal of Experimental Education, 86, 11-29. https://doi.org/10.1080/00220973.2017.1380589
- Priniski, S. J., Rosenzweig, E. Q., Canning, E. A., Hecht, C. A., Tibbetts, Y., Hyde, J. S., & Harackiewicz, J. M. (2019). The benefits of combining value for the self and others in utility-value interventions. Journal of Educational Psychology, 111, 1478-1497.https://doi.org/10.1037/edu0000343
- Rosenzweig, E. Q., Harackiewicz, J. M., Priniski, S. J., Hecht, C. A., Canning, E. A., Tibbetts, Y., & Hyde, J. S. (2018). Choose your own intervention: Using choice to enhance the effectiveness of a utility-value intervention. Motivation Science. 5, 269–276 . https://doi.org/10.1037/mot0000113
- Rosenzweig, E. Q., Hulleman, C. S., Barron, K. E., Kosovich, J. J., Priniski, S. J., & Wigfield, A. (2019). The promises and pitfalls of adapting utility value interventions for online mathematics courses. Journal of Experimental Education, 87, 332-352. https://doi.org/10.1080/00220973.2018.1496059
- Wang, Y., Rocabado, G. A., Lewis, J. E., & Lewis, S. E. (2020). Prompts to promote success: Evaluating utility value and growth mindset interventions on general chemistry students' attitude and academic performance. Journal of Chemical Education, 98, 1476-1488. https://doi.org/10.1021/acs.jchemed.0c01497

Math Hunger Sample Problem

Round 2. Arena 1

Bacteria come in a variety of shapes, including spherical, cylindrical, and spiral. Bacteria with a cylindrical shape are often referred to as rod-shaped bacteria, or *bacilli*. Bacilli are not strictly cylindrical, but can be approximated as a cylinder with rounded ends. We could model the shape of a bacillus using a cylinder with hemispheres on either end. Let the cylinder has height h and radius r; then the radius of each hemisphere is also r (see figure below).



The volume of the cell is the volume of the cylinder plus the volume of two hemispheres, that is

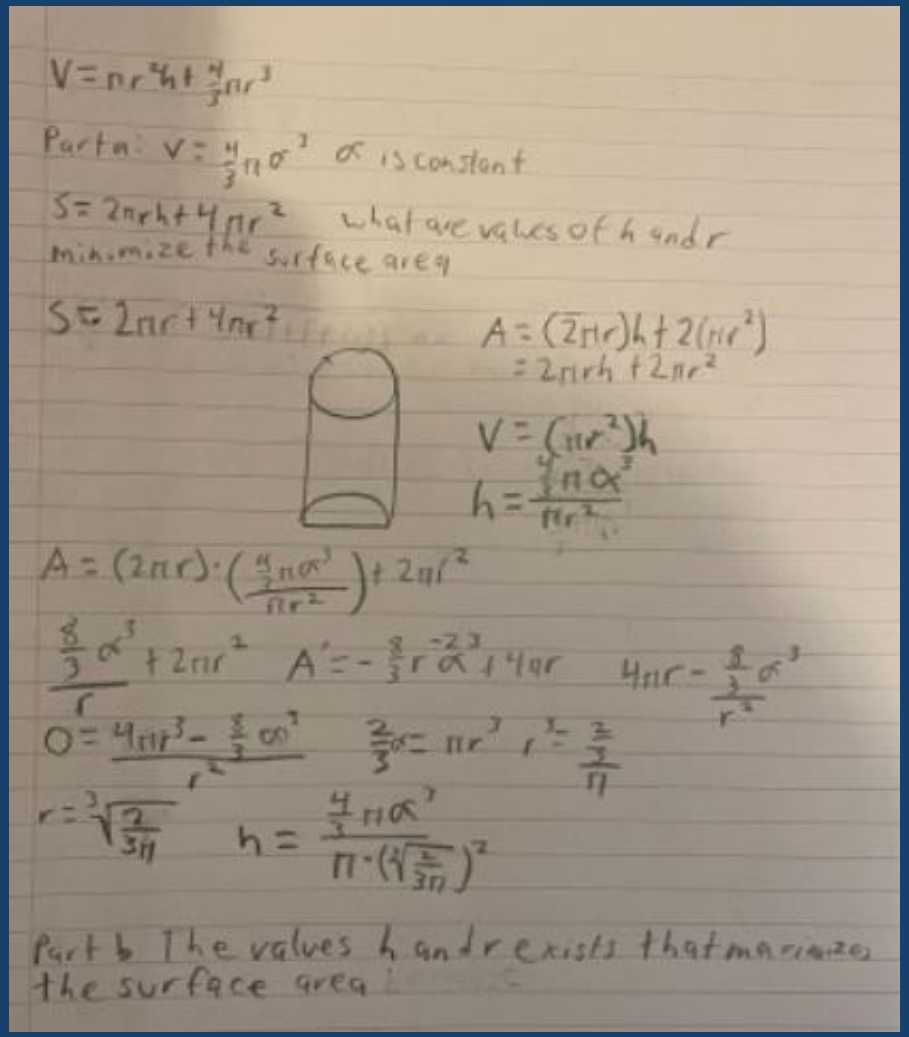
$$V = \pi r^2 h + \frac{4}{3}\pi r^3,$$

Here $\pi r^2 h$ is the volume of the cylinder and $\frac{4}{3}\pi r^3$ is the volume of two hemispheres (or one whole sphere).

The surface area of the cell is the surface area of the side of the cylinder plus the surface area of the two hemispheres, namely,

$$S = 2\pi r h + 4\pi r^2.$$

- Suppose that the volume of the bacillus is fixed to be $V = \frac{4}{3}\pi\alpha^3$, where α is a constant that is specific to a species of bacilli. If there is a loss through the cell surface (e.g., it is a semipermiable membrane) of some internal compound that is costly for the cell to produce, then we might be interested in considering a cell shape that minimizes the surface area. What values of h and r minimize the surface area if the volume is fixed to be $V = \frac{4}{3}\pi\alpha^3$?
- Now we consider the opposite situation when bacteria receives important nutrients through its surface and thus benefits from a larger surface area. Do values h and r exist that maximize the surface area if the volume it fixed to be $V = \frac{4}{3}\pi\alpha^3$?
- Consider expressions for S and h that are obtained in the previous parts under the assumption that the volume of the bacillus it fixed to be $V = \frac{4}{3}\pi\alpha^3$? What happens to values of S and h as $r \to 0^+$?
- Although the sizes differ considerably among different bacteria species, the radius of bacilli is between 0.25 μm to 0.5 μm with a length h in the range of 1.0 μm to 4.0 μm. What could this mean for the above models?



Student solutions range from a power point, to recorded video, to hand-written (with mistakes)