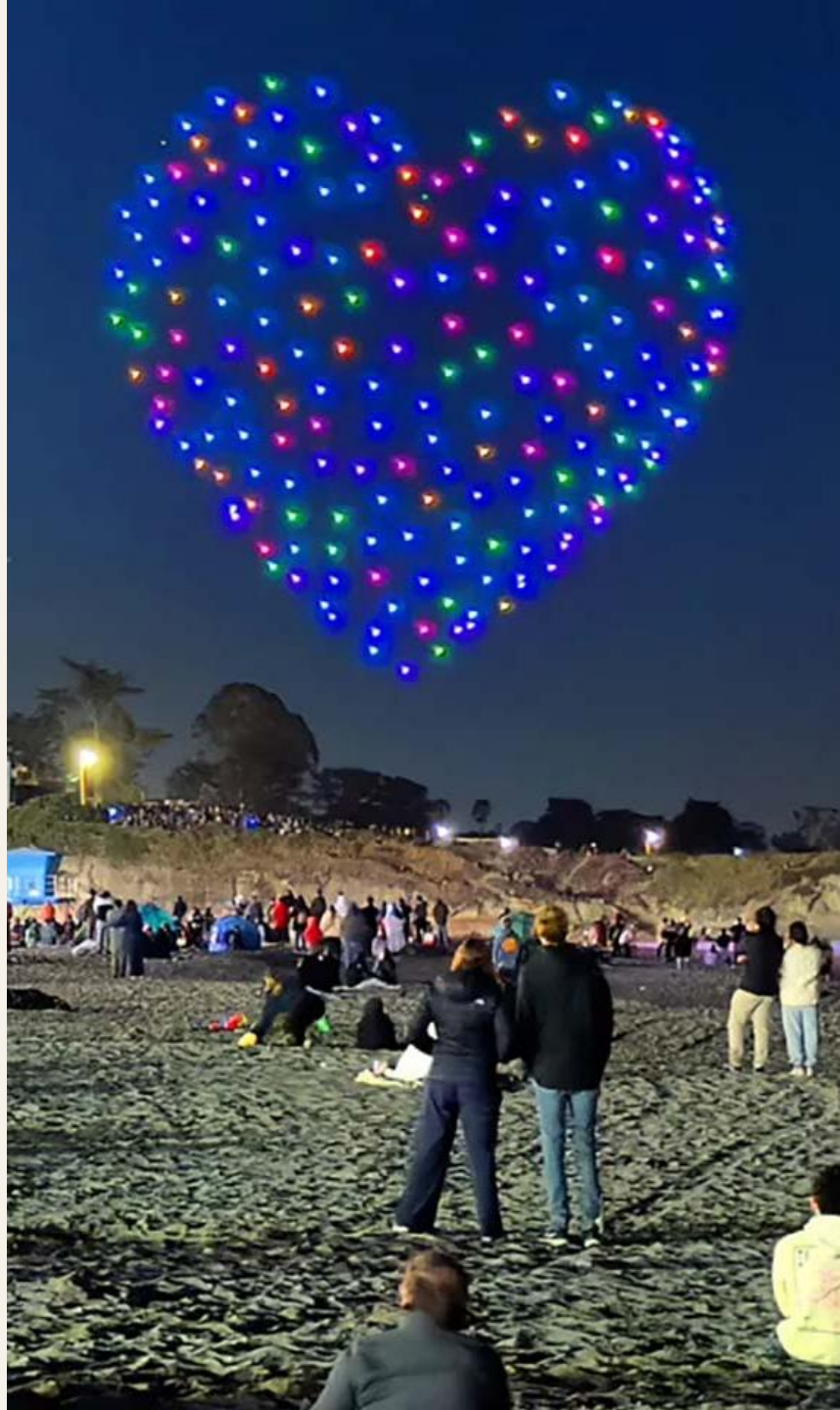
High Tech and No Tech

intention and pedagogy in a modeling-based calculus course.

Marty Weissman, University of California, Santa Cruz
OLSUME, October 6, 2026
(Style, charts, diagrams with Claude Sonnet 5.5)



Outline

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About Math 16A/B



History: Where Math 16 came from

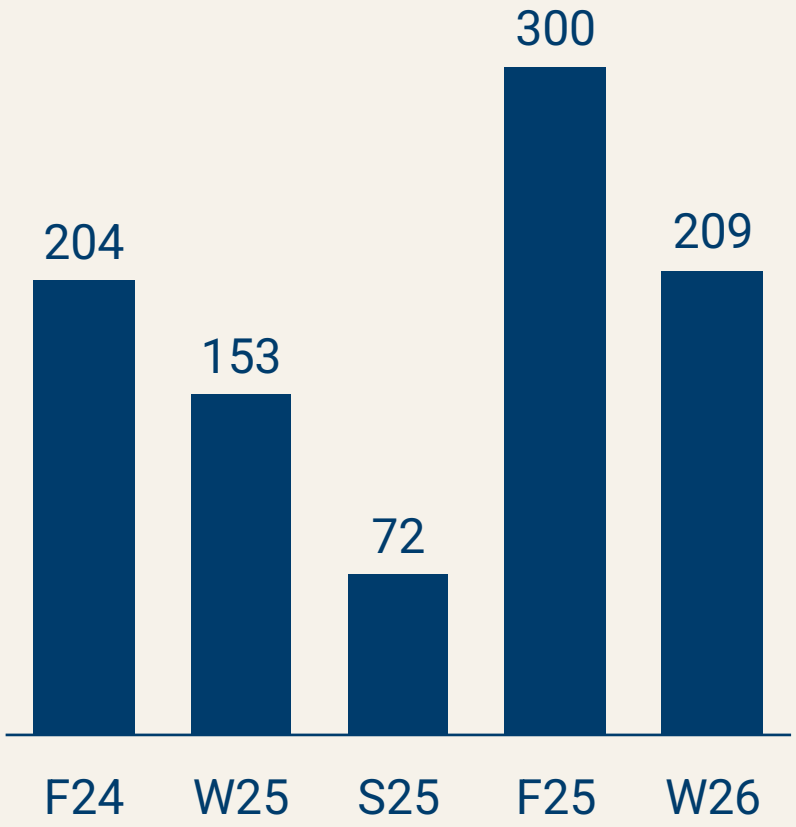
2006 – present: I'm a math professor at UC Santa Cruz, specializing in number theory and representation theory.

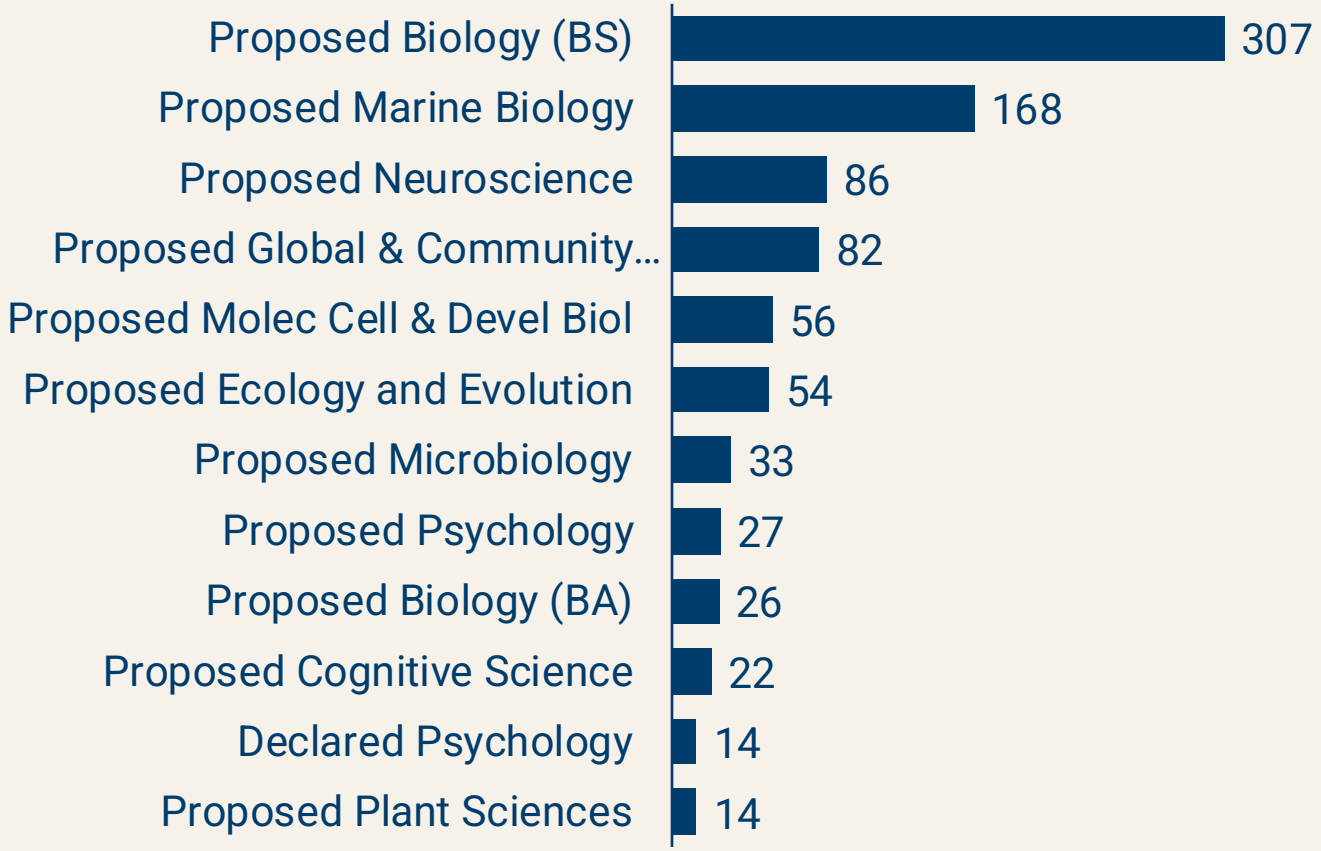
2013-2023: I built some biology experience (teaching and research).

2012? – present: UCLA introduced a radical alternative to calculus for its 1000s of biology majors: LS 30A/B and their book "Modeling Life"

2023-present: I was asked to adapt UCLAs class for UCSC, and said yes. Math 16A/B is now in its third year!

History: Math 16A Enrollment





Challenging questions for the course

How does one teach mathematics while centering biology?

How does one teach during the tumultuous beginnings of AI?

How does one teach students with unreliable math preparation?

How does one find instructors and teaching assistants for such a class?

Challenging questions for the course

How does one teach mathematics while centering biology?

Care about biology. Careful composition. Be honest.

How does one teach during the tumultuous beginnings of AI?

Intentional high tech and no tech moments. Active learning.

How does one teach students with unreliable math preparation?

Basic numeracy for everyone. Choose a few key foundations.

How does one find instructors and teaching assistants for such a class?

Professional development. Bribes. Arm twisting. Ongoing struggle!

Rhythm (Math 16A)

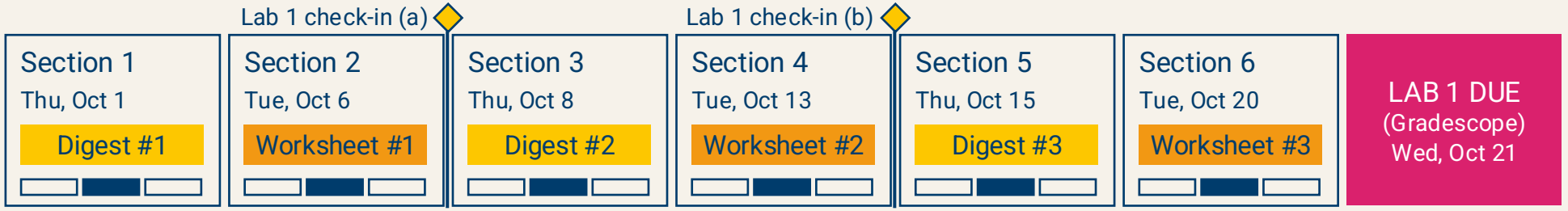
1 week

Weekly Rhythm

Monday	Tuesday	Wednesday	Thursday	Friday
Lecture	Discussion section	Lecture	Discussion section	Teaching-team meeting
~300 students	40 students with TA&ALF. *Worksheet due on paper*	~300 students	40 students with TA&ALF *Lecture digest due on paper,*	Debrief and planning Whole team

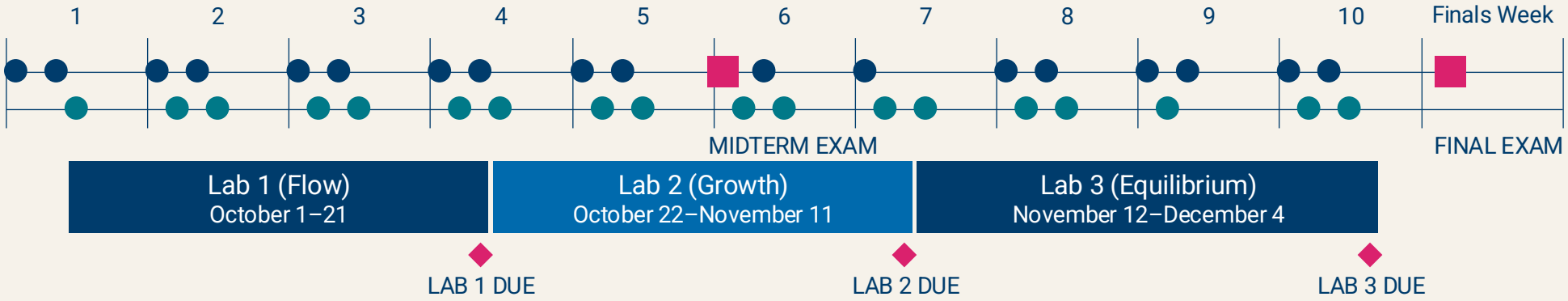
3 weeks

Lab 1 (Flow)



10 weeks

- 18 lectures
- 18 sections



martyweissman.github.io/math16

Core Course Resources (free for use/adaptation!)

Lab Manual v3.0

- Lab 1 (Flow)
  October 1–21
- Lab 2 (Growth)
  October 22–November 11
- Lab 3 (Equilibrium)
  November 12–December 4

Teaching Team Manual

Modeling synthesizer



martyweissman.github.io/math16

Worksheets

- #1 Tabulating Change
- #2 Trajectories and Time Series
- #3 Change Equations to Tables
- #4 Linear Models
- #5 Power Functions
- #6 Exponential to Equilibrium
- #7 Phase Portraits
- #8 Two Populations
- #9 Generalized Lotka-Volterra (DRAFT)

Worksheets are printed and completed by hand.

Lecture Digests

#1 #2 #3 #4 #5 #6 #7 #8 #9

Lecture Digest Template

Lecture digests are handwritten structured notes.

About 300 students and a teaching team of sixteen

Marty (instructor)

four TAs

eight Active Learning Facilitators (ALFs)

two people from ACE (Academic Excellence Program)

a tutor from Learning Support Services

Live Problems & Slides

1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18

No tech



Equations as an expressive language

Question for participants:

What is an **equation** for a first-year biology student?

Answers in the Zoom chat please.

$$PV = Nk_BT$$

$$P' = \beta P\left(1 - \frac{P}{c}\right)$$

$$A(t) = A(0) \cdot (0.5)^{t/t_{1/2}}$$

Equations as an expressive language

What is an **equation** for a first-year biology student?

Something with a “=“ in it.

Something to “solve”.

Something to “plug into”.

Something to regurgitate, or write on your cheat-sheet if you have a nice teacher.

$$PV = Nk_BT$$

$$P' = \beta P\left(1 - \frac{P}{c}\right)$$

$$A(t) = A(0) \cdot (0.5)^{t/t_{1/2}}$$

Equations as an expressive language

What is an **equation** for a scientist?

A sentence that expresses a precise relationship between quantities, whether the individual quantities are known or unknown.

How do we help students understand equations in this way?

Structured reading and writing, requiring the integration of symbolic mathematics with academic English.

Example in words:	A child grows 2 inches per year.
State variable:	Let H be the height of the child (in inches).
Time interval:	Δt = 1 year.
Change equation:	$\Delta H/\Delta t$ = 2 inches per year.

From page Lang1 of the Lab Manual 3.0

Equations as an expressive language

Complete the sentence exercises.

How do we help students understand equations in this way?

A first exercise.

Example in words:	After her parachute opens, a skydiver descends at a speed of 5 meters per second.
State variable:	Let _____
Time interval:	Δt = _____.
Change equation:	_____

From page Lang1 of the Lab Manual 3.0

From situations to equations and back again

Consider the equation $\Delta S/\Delta t = 0.07S$. Which of the following situations could this accurately describe?

A A slug grows 7% longer each week.

B A slug grows 7mm longer each week

C The length of a slug changes every 7 days.

D Only 7% of banana slugs are growing.

E Banana slugs are 7% longer than ordinary slugs.

Coyotes die if they don't eat enough moose, and moose thrive if the coyotes don't eat them. Let C be the number of coyotes, and M the number of moose. Which of the following equations could describe how the coyote population changes?

A $\Delta C/\Delta t = -0.2C + 0.1MC$.

B $\Delta C/\Delta t = 0.2C - 0.1M$.

C $\Delta C/\Delta t = 0.2C + 0.1MC$.

D $\Delta C/\Delta t = 0.2C - 0.1MC$.

E $\Delta C/\Delta t = -0.2C - 0.1MC$.

Sample questions from the midterm exam

Change equations and tables

The central object of study in Math 16 (and UCLA's LS30) is the 'Change Equation', a friendly name for what mathematicians call ODE. Students learn to express relationships with change equations. At the same time, they know how change equations provide concrete predictions – they learn to tabulate!

$$\Delta G/\Delta t = m - sIG$$

$$\Delta I/\Delta t = qb\frac{G^2}{1+G^2} - \gamma I$$

A "minimal model" of the insulin-glucose system

t	G	I	ΔG	ΔI
0	2	1		
1				
2				
3				

From page IG7 of the Lab Manual 3.0

Change equations and tables

The central object of study in Math 16 (and UCLA's LS30) is the 'Change Equation', a friendly name for what mathematicians call ODE. Students learn to express relationships with change equations. At the same time, they know how change equations provide concrete predictions – they learn to tabulate!

$$\Delta G/\Delta t = 1 - IG$$

$$\Delta I/\Delta t = \frac{G^2}{1+G^2} - I$$

Tabulate your predictions! Complete t=1 in Zoom chat.

A "minimal model" of the insulin-glucose system

t	G	I	ΔG	ΔI
0	2	1	-1	-0.2
1	1	0.8		
2				
3				

From page IG7 of the Lab Manual 3.0

Graphs are the central medium for quantitative biology

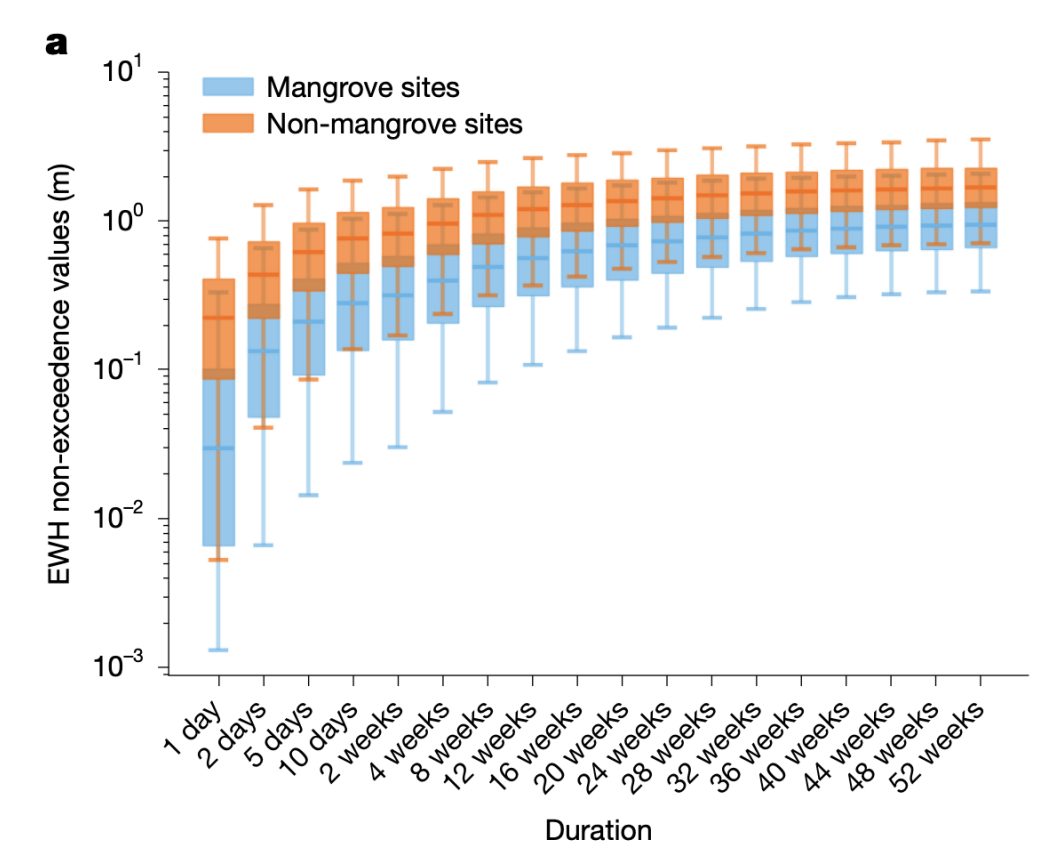


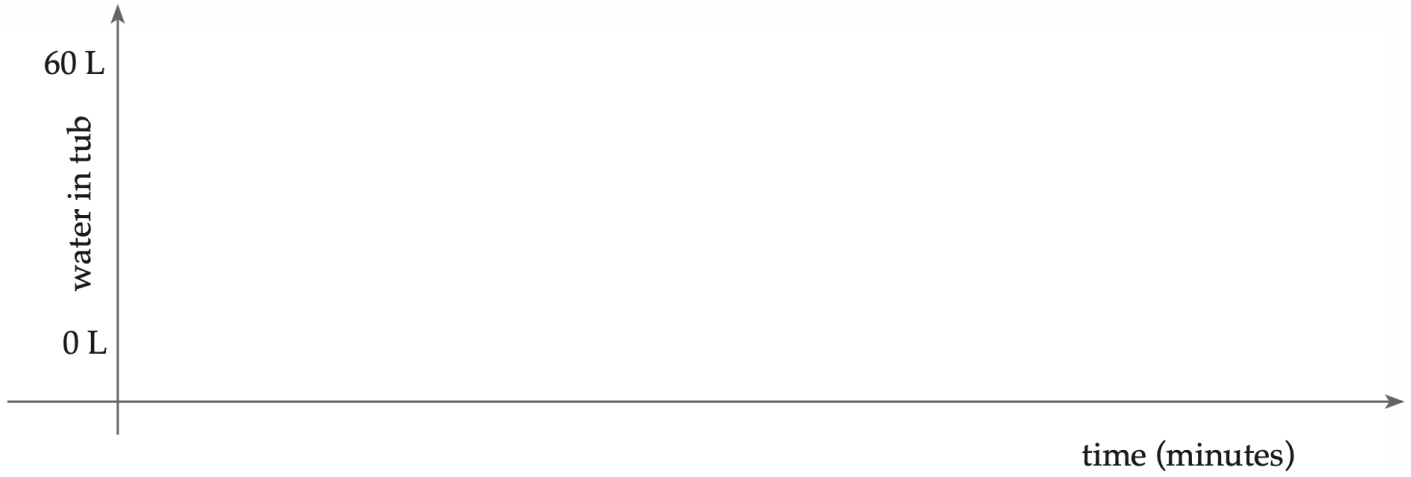
Figure 3(a) from *Global mangrove distribution on the open coast is controlled by waves*, by Wells et al., published in Nature, Sept 30, 2026.

This is a time-series of pairs of box-and-whiskers plots, on a semilog scale!

High quantitative complexity in a compact visual form. Established norm in most biology papers.

Graphs are the central medium for quantitative biology

BT2 Bathtub: graphing change



EX. On the chart above, draw a graph which represents the amount of water in the bathtub throughout the process of taking a bath. At the beginning and end, there should be 0 liters of water in your bath. Don't forget to **label the horizontal axis** with the number of minutes for each stage. **Label the stages** "Fill" and "Bathe" and "Drain."

An early exercise in the lab manual.

Students become familiar with the *elements* of quantitative graphics: axes and ticks, clear labels, line styles.

Students draw these by hand, even if computers produce graphs later in the course.

Building thinking classrooms

The BTC book by Dr. Peter Liljedahl introduces 14 practices. Here are #1 and #2.

1. What Types of Tasks We Use

If we want our students to think, we need to **give them something to think about**—something that will not only require thinking but also encourage thinking.

Math 16 practice

Students begin working on lab manual pages with thinking tasks, in required discussion sections (twice/week). They complete these pages for homework. This practice seems **AI-resistant**.

2. How We Form Collaborative Groups

We know from research that student collaboration is an important aspect of classroom practice, because when it functions as intended, it has a powerful impact on learning (Edwards & Jones, 2003; Hattie, 2009; Slavin, 1996)... when we frequently formed **visibly random groups**, within six weeks, 100% of students entered their groups with the mindset that they were not only going to think, but that they were going to contribute.

Math 16 practice

We use physical table-tent name-cards to enable human interaction, for old-fashioned attendance-taking, and for easy randomization every three weeks (a new group for each lab)

Source: https://www.buildingthinkingclassrooms.com/about-btc

Building thinking classrooms

3. Where Students Work

One of the most enduring institutional norms that exists in mathematics classrooms is students sitting at their desks (or tables) and writing in their notebooks. This turned out to be the workspace least conducive to thinking. What emerged as optimal was to have the students standing and working on vertical non-permanent surfaces (VNPSs) such as whiteboards, blackboards, or windows.

Math 16 practice

Discussion sections are in basement-like classrooms. But… we do have lots of movable rectangular tables and blackboards all around. So we make students write on the boards! The TA and ALF facilitate this, with a bit of training during teaching team meetings.

5. How We Answer Questions

A typical teacher will answer between 200 and 400 questions in a day, all of which fall into one of three categories:

1. proximity questions — the questions students ask because you happen to be close by
2. stop-thinking questions — the questions students ask so they can reduce their effort, the most common of which is, “Is this right?”
3. keep-thinking questions — the questions students ask so they can keep working, keep trying, and keep thinking.

Math 16 practice

We aim to keep students **thinking** throughout the 65 minute section, with keep-thinking questions from TA and ALF, and occasional (every 15-20 minute) attempts to synchronize and stay on task.

Source: https://www.buildingthinkingclassrooms.com/about-btc

High tech



Screens and thinking. Touching and learning

Explicit modality

We explicitly signal when the class is in no-tech or high-tech mode. In no-tech mode, students are asked to put all their laptops and phones away. In high-tech mode, we ask students to bring out their laptops – either one laptop per person or two laptops per group.

Idea: sometimes every student needs to practice the computer skills. Other times, everyone in the group needs to see the screen, but some will be operating, others will be taking notes, etc.

Questions

1. Do open screens crash the learning environment?
2. How do we make sure the students don't self-select as the computer-savvy students, depriving others of learning?
3. Are we teaching computational tools/skills? Are we using **computers to teach concepts**?

Turn the knobs, according to Daniel Dennett

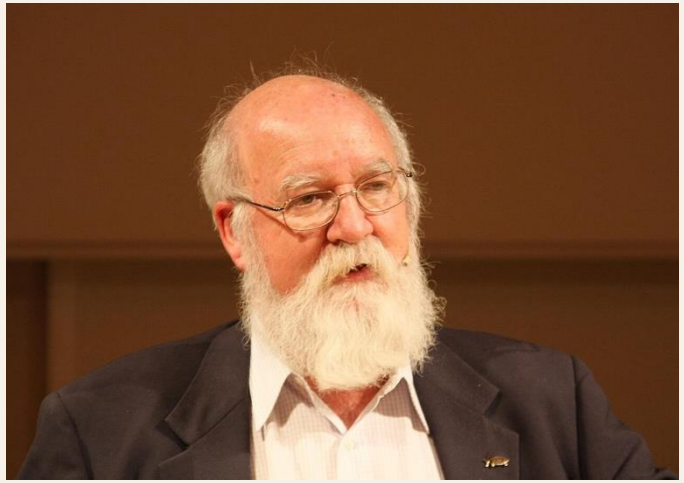


Photo: Mathias Schindler
CC BY-SA 3.0, via Wikimedia Commons

"A popular strategy in philosophy is to construct a certain sort of thought experiment I call an *intuition pump*. ... Intuition pumps are cunningly designed to focus the reader's attention on "the important" features, and to deflect the reader from bogging down in hard-to-follow details."

"When Doug Hofstadter and I composed *The Mind's I* back in 1982, he came up with just the right advice on this score: consider the **intuition pump** to be a tool with many settings, and "**turn all the knobs**" to see if the same intuitions still get pumped when you consider variations."

— Daniel Dennett, from *Intuition Pumps and Other Tools for Thinking*

Systems thinking for systems biologists.

To adapt Dennett's words, a *mathematical model* can focus the scientist's attention on "the important" features of a biological system, without getting bogged down in hard-to-follow details.

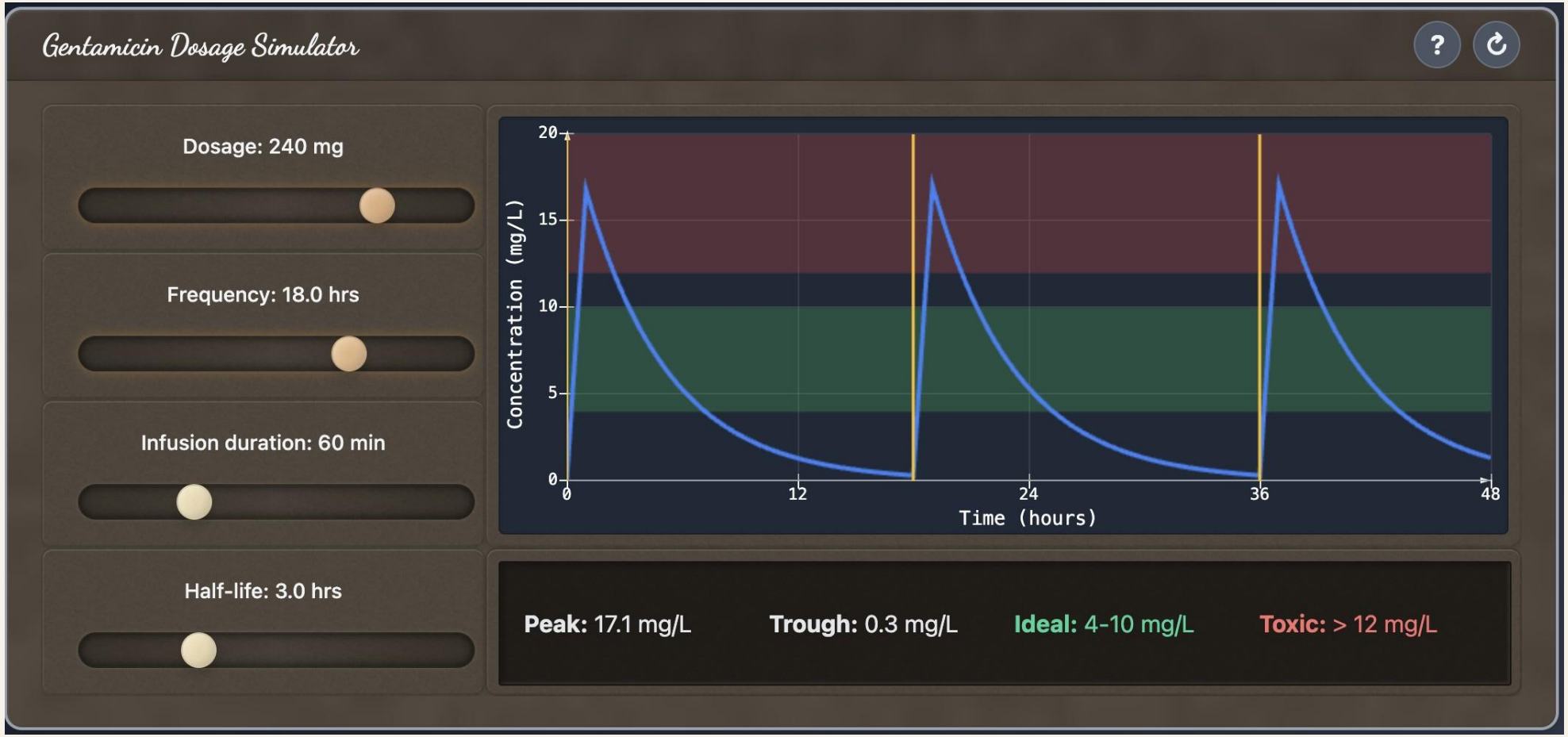
The important features are the state variables, the parameters, and their influence on each other.

We can follow Hofstadter's advice and "**turn the knobs**" by varying the parameters and seeing what happens to the system.

This is the modeling approach to *understanding* a system, and we do it with technology.

Modeling for drug dosage

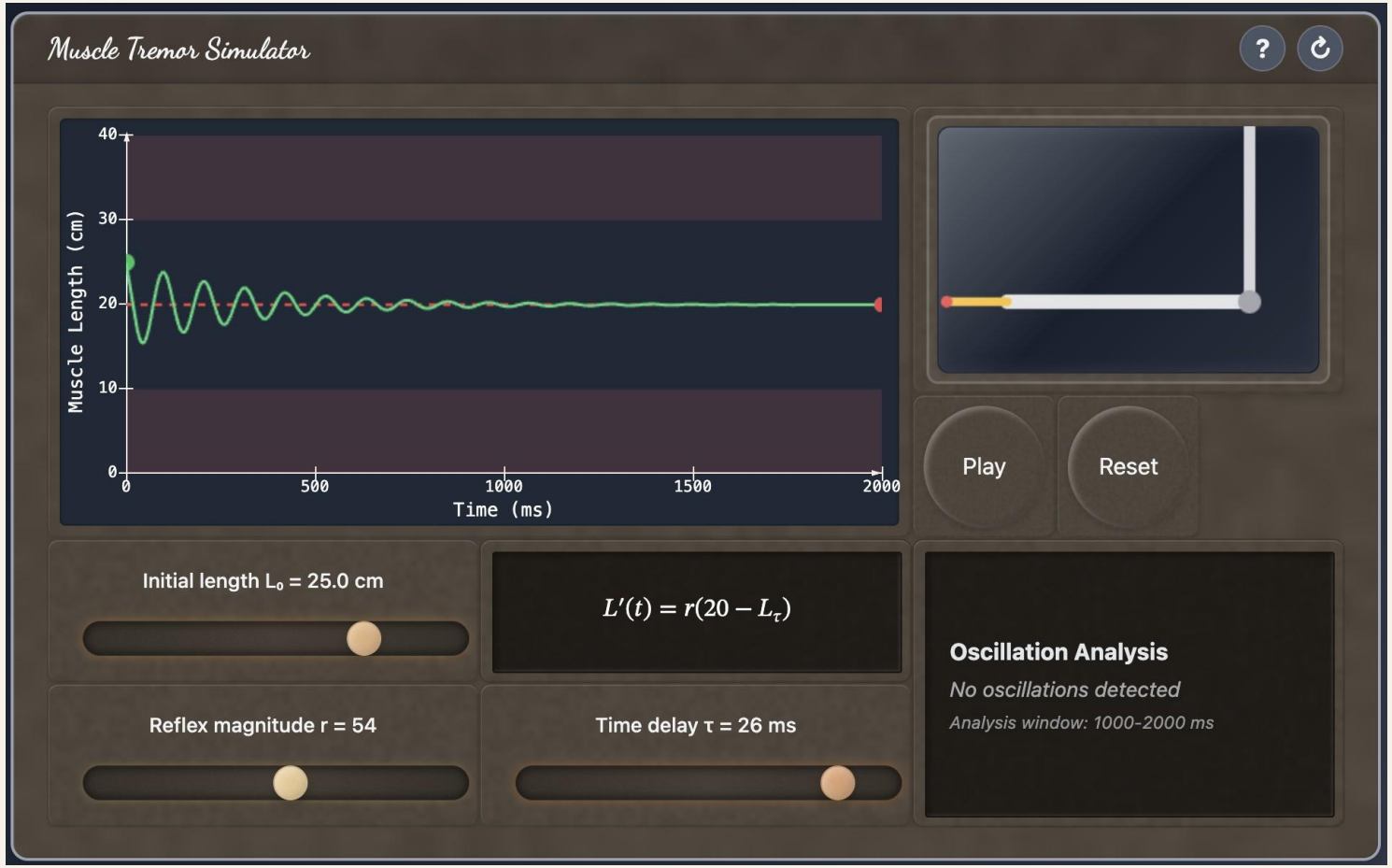
Can you adjust dosage, frequency, duration, to stay in the green zone?



Live tool

Muscle tremor simulation

Can you distinguish hyperreflexia from long latency by frequency of oscillation?



Live tool

EX. Set the reflex magnitude to r=60. The default time delay is 10 ms. Try increasing the time delay. At what critical time delay does the system display **sustained** oscillations? What frequency are these oscillations?

EX. Start with a time delay of 20 ms, and try increasing the reflex magnitude. This can happen, for example, if you are trying to counteract a weight pulling your elbow out of position. At what critical reflex magnitude does the system display sustained oscillations? What frequency are these oscillations?

EX. The brain normally suppresses the sensitivity of peripheral reflexes. In some **stroke** patients, this suppression is lost, and the person's muscles will react too strongly (hyperreflexia). A **different kind of** problem is a slowing of the reflex loop itself. In some cerebellar diseases, the long-latency reflexes appear to be delayed, which increases τ.

Using the Muscle Tremor Simulator as a guide, how might the **frequency** of tremor distinguish a patient whose tremor arises from hyperreflexia from one whose tremor arises from an increased time delay?

Dimensions of model evaluation

Accurate descriptions: does the model accurately describe previous observations, when appropriate parameters are chosen?

Accurate predictions: does the model accurately predict future observations?

Parsimony: does the model have more parameters than should be necessary, or just a few necessary ones? Does the model only "fit" the data because a zillion parameters are tweaked the right way?

Robust: do small changes in assumptions or parameters destroy the utility of the model? Or does the model hold up, with minor adjustments?

Adaptable: can the model be easily adapted to slightly different situations or by adding layers of complexity as needed?

Generalizable: does the model apply to a broad range of circumstances, or just to the very specific situation it is designed for?

+ Pedagogical Value

Interpretable

Can one easily interpret each term of the model to understand how different factors will change the outcomes?

Insightful

Does the model provide insight that would be difficult to find by simple observation alone?

AI and teaching tools (mostly Claude)

1. Vibe-coding the full Modeling Synthesizer suite, with decent user interface and reusable components which can be easily assembled for new tools.
2. Proofreading and editing the entire lab manual via InDesign. (Versions 1.0 and 2.0 all done without AI.) Converting handwritten solutions for the new Instructor Edition in Version 3.0.
3. Randomizing and shuffling exam questions, creating multiple versions, aligning to learning objectives, etc.
4. Typesetting worksheets.
5. Creating websites to organize and gather resources.
6. Styling presentations like this one.
7. Analyzing data such as student surveys.

Good intentions



Intentions

UCLA demonstrated that their course (LS 30) had the following positive impacts:

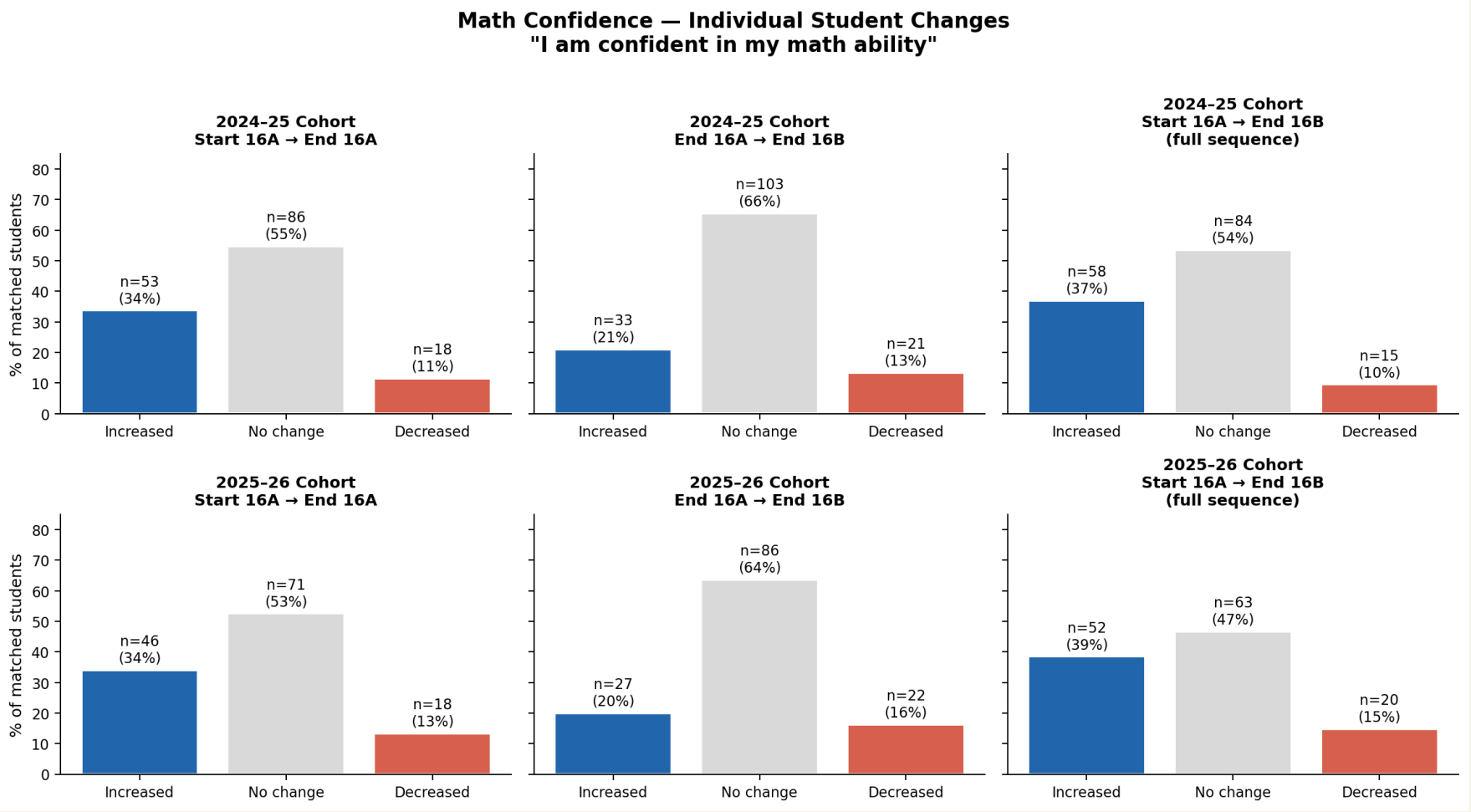
- Increased student confidence in mathematics. Self-efficacy!
- Stronger performance in downstream courses like chemistry and physics, when compared to traditional class. Addresses concerns about fluffy math hurting students later.
- Admission to med schools still ok!
- No need for math placement at all… no math prerequisite for LS 30A/B. “Student success” improves!

Those convinced me and UCSC to build Math 16.

The big questions to me:

1. Are those successes at UCLA ongoing? (I think so!)
2. Can other institutions enjoy those successes? (Maybe!)
3. Are there other positive impacts to look at? (I think so!)

I am confident that Math 16 increases student confidence.



Other successes at UCLA.

Strong performance in downstream courses like chemistry and physics. Addresses concerns about fluffy math hurting students later.	*Seems* ok at UCSC. It's still a bit early to tell, but I think we're not doing any harm! Very difficult to tell because of instructor inconsistency in grading, and the students who *choose* to take Math 16A/B are very different from those who choose to take more traditional calculus Math 11A/B or 19A/B.
Admission to med schools still ok!	Seems ok, but our med school admission rate is way lower than UCLA anyways. We use the same approach as UCLA, providing letters to med schools and other programs when needed.
No need for math placement at all… no math prerequisite for LS 30A/B. "Student success" improves!	I think this is ok, but my UCSC colleagues pushed for math prerequisites for Math 16A/B. So now it's got the same prereqs as traditional calculus.

Qualitative feedback… top positives synthesized by Claude.

~90% of responses

Science-math connection and real-world relevance

Students overwhelmingly expressed that the class transformed their view of mathematics by explicitly linking it to biological and ecological applications. They moved from seeing math as abstract problem-solving to understanding it as a practical tool for modeling populations, drug dosages, glucose-insulin systems, and predator-prey interactions. Many stated that before the class they thought “math was just formulas” or “pointless,” but now they see “math is connected to science,” “math explains how the world works,” and “math is integrated into nature.” This shift from seeing mathematics as isolated from practical application was the dominant theme across nearly all positive responses.

~75% of responses

Conceptual understanding over memorization

Students appreciated that the class emphasized understanding why mathematical models work rather than memorizing formulas or solving for x by rote. They noted that the course was “conceptual,” “not traditional calculus,” and focused on applying ideas rather than procedural problem-solving. Many remarked that seeing derivatives, exponential growth, and logistic functions in biological contexts made these concepts “make sense” in ways that traditional calculus did not. Students frequently contrasted this with high school math, where they “just solved problems” without understanding purpose.

Thank you and resources!

My email address	weissman@ucsc.edu
Course flow and public resources	github math16 site
Modeling synthesizer	github modeling synthesizer site
Modeling Life	by Alan Garfinkel, Jane Shevtsov, and Yina Guo published by Springer-Verlag