MOOCs, Textbooks, and a Radical DE Course

David P. Feldman

College of the Atlantic

College of the Atlantic (Bar Harbor, Maine, USA) is located on the traditional lands of the Penobscot and Passamaquoddy tribes, members of the Wabanaki Confederacy.

12 February 2022

Outline and Goals

Outline

1. Discuss my experiences developing and teaching a radically modeling-focused DE course
2. Share thoughts on the importance of emphasizing the very diverse roles that models play in the sciences
3. Briefly discuss two related projects:
    1. Two Massive Open Online Courses
    2. Writing two math books

Context

- I teach at a small (350 student) interdisciplinary liberal arts college.
- All students design their own major.
- Faculty are not organized by department.
- I am the only faculty member in mathematics or physics.
- I am a theoretical and computational physicist.

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods
- Students are expected to have some background in coding, preferably python

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods
- Students are expected to have some background in coding, preferably python
- Cover Euler's method in detail.

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods
- Students are expected to have some background in coding, preferably python
- Cover Euler's method in detail.
- Then `odeint` in python to solve systems of ODEs
- `matplotlib`[1] for visualizing solutions

[1] I miss `gnuplot`. Those were simpler times.

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods
- Students are expected to have some background in coding, preferably python
- Cover Euler's method in detail.
- Then `odeint` in python to solve systems of ODEs
- `matplotlib`[1] for visualizing solutions
- Examples mainly from epidemiology (SIR) and population ecology (Lotka–Volterra)

[1] I miss `gnuplot`. Those were simpler times.

Differential Equations at COA

- Emphasis on what an ODE **is** instead of how to solve it
- Very little coverage of analytic methods
- Students are expected to have some background in coding, preferably python
- Cover Euler's method in detail.
- Then `odeint` in python to solve systems of ODEs
- `matplotlib`[1] for visualizing solutions
- Examples mainly from epidemiology (SIR) and population ecology (Lotka–Volterra)
- Spend some time on diffusion equations and "spatializing" ODEs

[1] I miss `gnuplot`. Those were simpler times.

Course Elements

1. Several problem sets

Course Elements

1. Several problem sets
2. Active learning in class, live coding

Course Elements

1. Several problem sets
2. Active learning in class, live coding
3. A term-long **research project**:
    1. Midterm preliminary talk
    2. End-of-term talk
    3. End-of-term technical paper
    4. (Often projects center around reproducing a result from a peer-reviewed paper.)

Course Elements

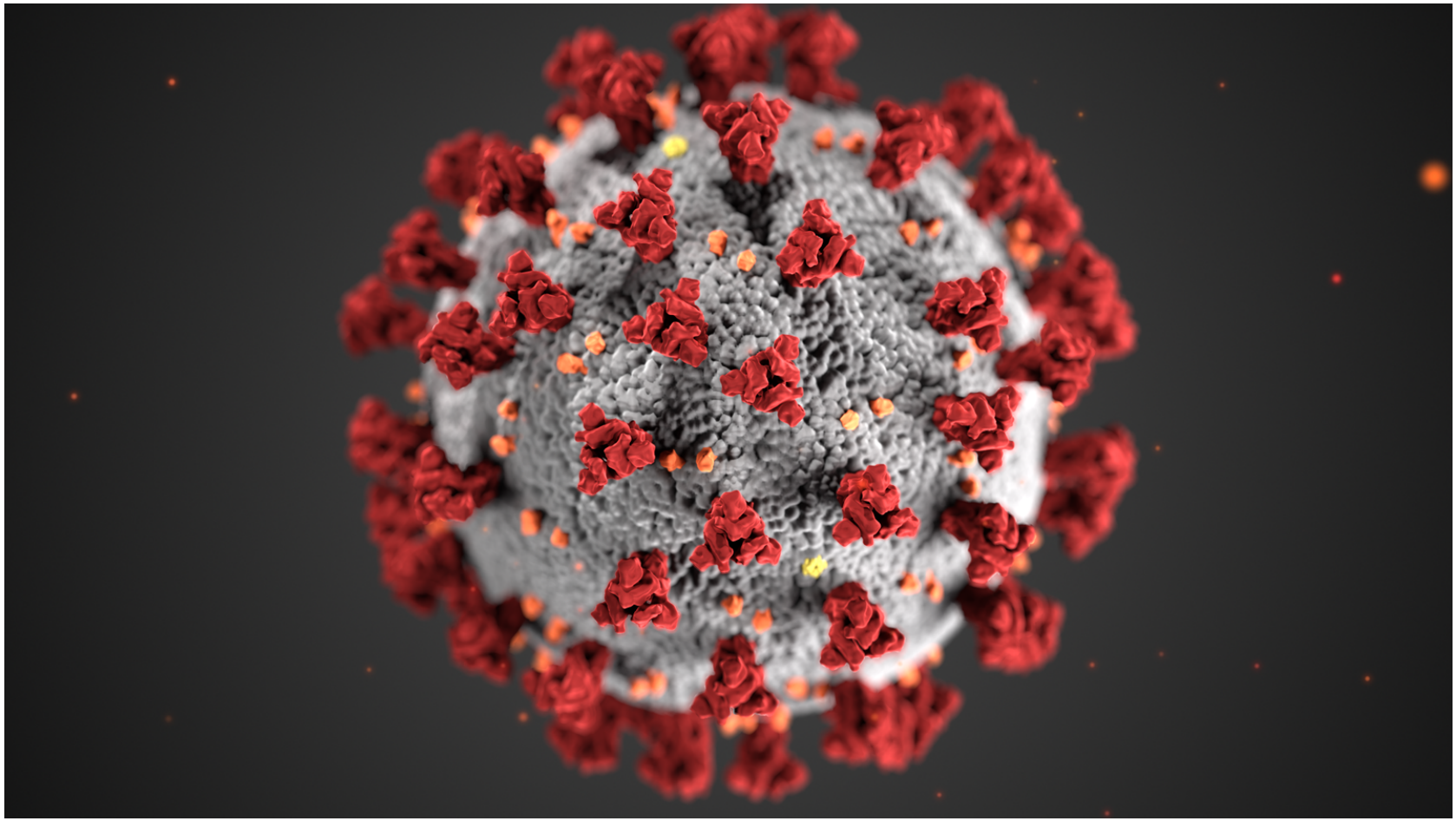
1. Several problem sets
2. Active learning in class, live coding
3. A term-long **research project**:
    1. Midterm preliminary talk
    2. End-of-term talk
    3. End-of-term technical paper
    4. (Often projects center around reproducing a result from a peer-reviewed paper.)
4. Instruction in research skills:
    1. What **is** research? (Booth, Wayne C., et al. *The craft of research.* University of Chicago press, 2003.)
    2. Searching peer-reviewed literature
    3. How to give a scientific talk
    4. (Optional) introduction to LaTeX

Winter 2020 Project Topics Included:

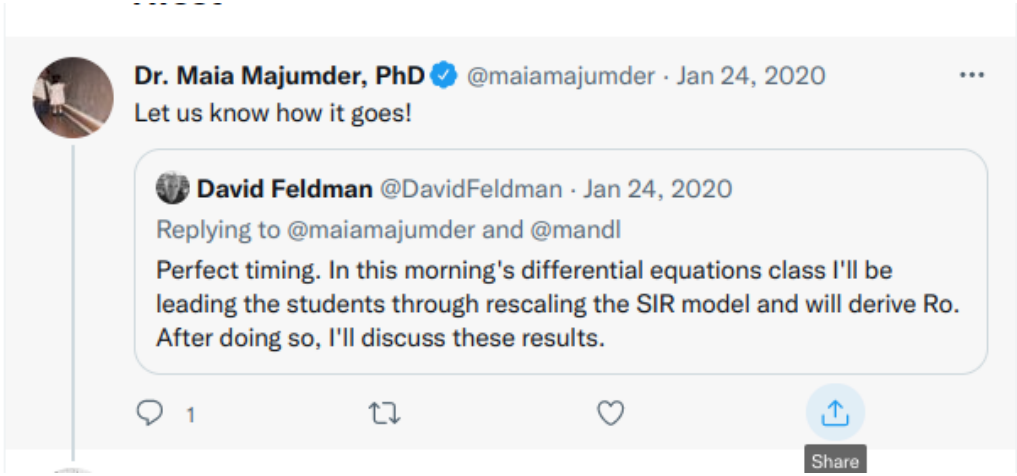
- Relation between atmospheric and oceanic CO_2
- Evolutionary dynamics and the replicator equation
- Simple models of sea-level rise
- Models of harmful algae blooms
- Dengue fever epidemiology
- (Delayed) differential equation models of love
- Transitions from communism to capitalism
- Models of shifts in US politics
- Models of linguistic change in US English
- Floral changes in Pleistocene-Holocene transition
- and....

Winter 2020 Project Topics Included:

COVID-19



Winter 2020 Project Topics Included:



A Fun Class Activity: Model Jeopardy

Give students a set of differential equations, ask them in groups to figure out what it could be a model of, and come up with a possible meaning for each variable and parameter.

$$\begin{aligned} \frac{dH}{dt} &= rH\left(1-\frac{H}{K}\right)-\frac{kPH}{H+D}\,, \\ \frac{dP}{dt} &= sP\left(1-\frac{P}{\gamma H}\right)\,. \end{aligned} \tag{1}$$

I didn't think up this activity, but I can't remember where I first heard of it.

A Fun Class Activity: Model Jeopardy

Give students a set of differential equations, ask them in groups to figure out what it could be a model of, and come up with a possible meaning for each variable and parameter.

$$\begin{aligned} \frac{dA}{dt} &= r_a A\left(1-\frac{A}{K_A}\right)+\alpha AB\ , \\ \frac{dB}{dt} &= r_b B\left(1-\frac{B}{K_b}\right)+\beta AB\ . \end{aligned} \tag{2}$$

Reflecting on the course

- Some strengths
  - Students engage with math as something to think/experiment/explore/play with.
  - Combines analytic and computational approaches
  - Students find research skills learned valuable and transferable

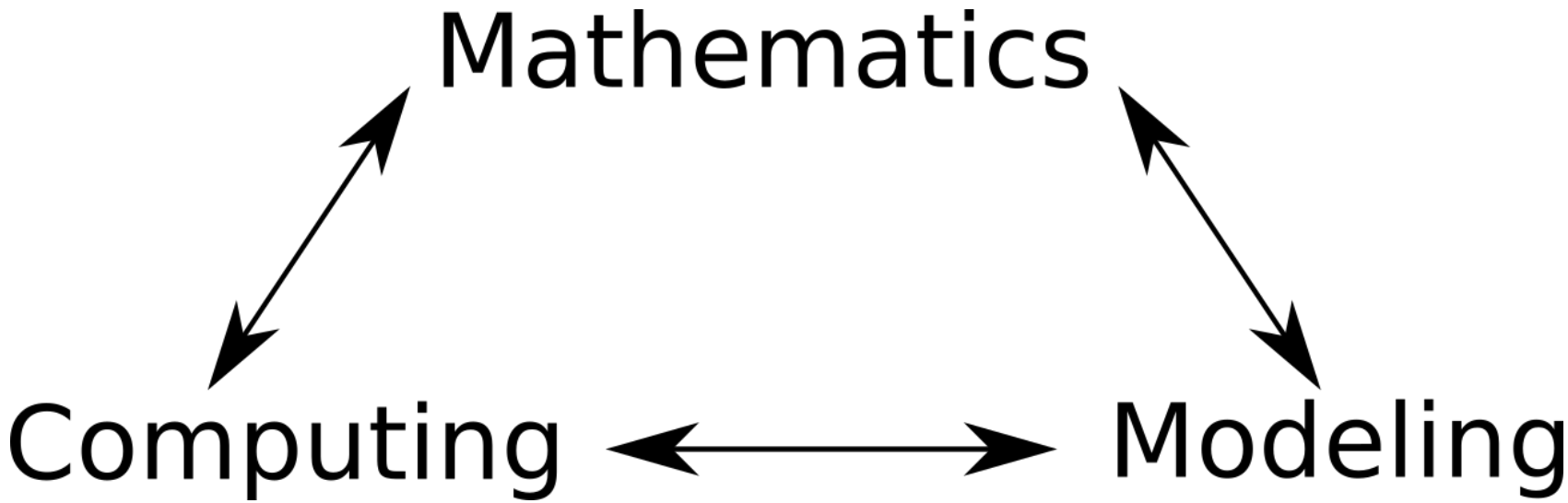
Reflecting on the course

- Some strengths
  - Students engage with math as something to think/experiment/explore/play with.
  - Combines analytic and computational approaches
  - Students find research skills learned valuable and transferable
- Some challenges
  - Some projects never quite achieve lift-off
  - How to have the right amount of scaffolding for students?
  - Might have gone too far toward modeling/computation.

Reflecting on the course

- Some strengths
  - Students engage with math as something to think/experiment/explore/play with.
  - Combines analytic and computational approaches
  - Students find research skills learned valuable and transferable
- Some challenges
  - Some projects never quite achieve lift-off
  - How to have the right amount of scaffolding for students?
  - Might have gone too far toward modeling/computation.
- Next time: focus entirely on epidemiology as a case study?

Three connected areas that should be taught together



All the arrows go both ways.

These topics are too often taught in separate classes, sometimes in separate departments.

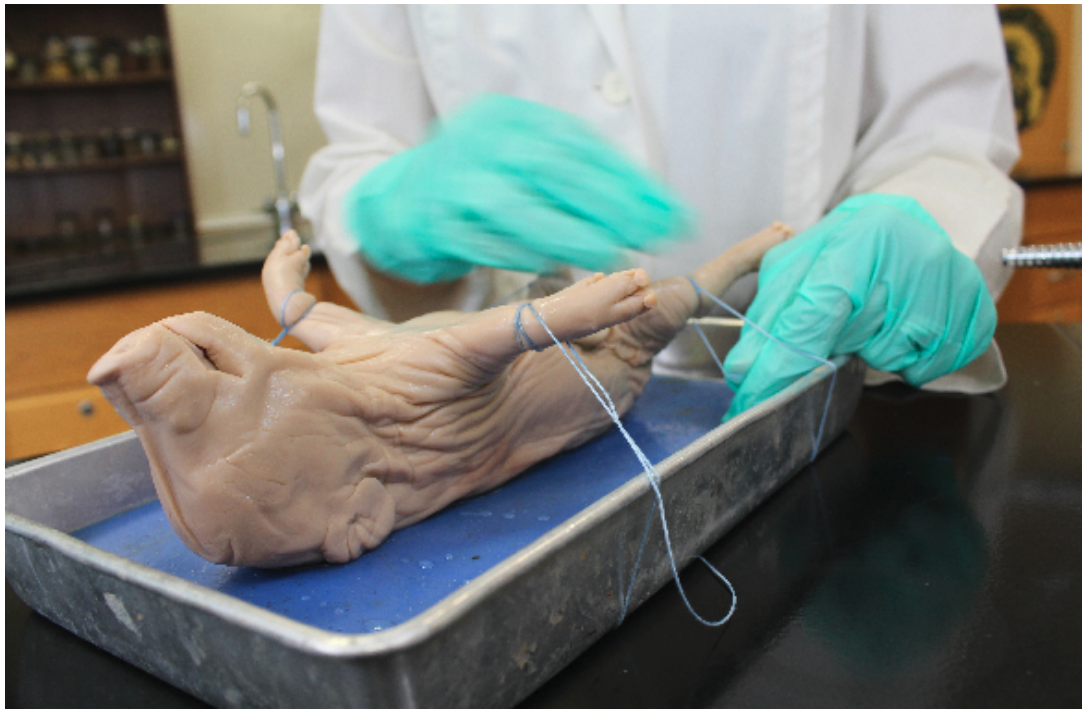
Different Ways of Thinking about Models

- Not all models are predictive or representational.
- Some are more like caricatures, designed to capture in a simplified way the essence of a phenomenon.

Paintings are More Valuable than Photographs for Bird Identification

- https://www.galleryone.com/fineart/PETBA3.html
- https://indianaaudubon.org/portfolio/baltimore-oriole/

A Model of a Human: A Fetal Pig



Another Model of a Human: A Mannequin

Example from Blanchard, Paul, Robert L. Devaney, and Glen R. Hall. *Differential equations*. Cengage Learning, 2012.

Which is Better Model of a Human Being?

Pig/Mannequin example from Blanchard, Paul, Robert L. Devaney, and Glen R. Hall. *Differential equations*. Cengage Learning, 2012.

Which is Better Model of a Human Being?

- The question doesn't make sense.

Pig/Mannequin example from Blanchard, Paul, Robert L. Devaney, and Glen R. Hall. *Differential equations*. Cengage Learning, 2012.

Which is Better Model of a Human Being?

- The question doesn't make sense.
- Contexts, goals, motivations matters.

Pig/Mannequin example from Blanchard, Paul, Robert L. Devaney, and Glen R. Hall. *Differential equations*. Cengage Learning, 2012.

Which is Better Model of a Human Being?

- The question doesn't make sense.
- Contexts, goals, motivations matters.
- Note that in neither case does it make sense to critique the model as being not realistic enough.
- A lack of realism is what makes the model effective.

Pig/Mannequin example from Blanchard, Paul, Robert L. Devaney, and Glen R. Hall. *Differential equations*. Cengage Learning, 2012.

Levels of Abstraction: Ontological Status of Variables

- Position
- Temperature
- Population
- Densities
- Utility

First-models, heuristic models, statistical models....

So.... How to think about models?

So.... How to think about models?

- George Box: All models are wrong, but some are useful

So.... How to think about models?

- ~~George Box: All models are wrong, but some are useful~~

So.... How to think about models?

- ~~George Box: All models are wrong, but some are useful~~
- Richard Levins: Models either enlighten or obscure[2].
- What is the purpose of the model?

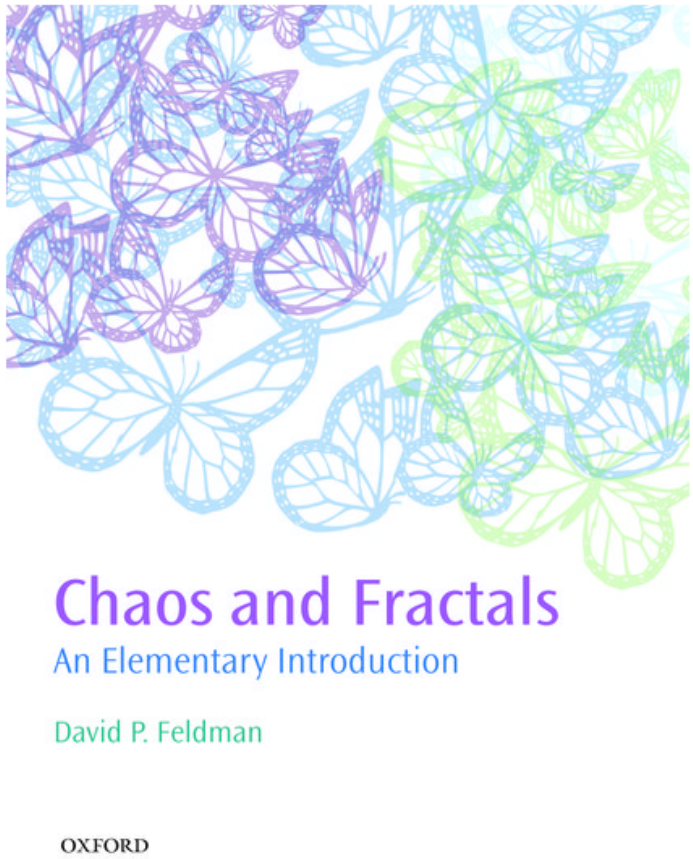
[2]Levins, Richard. Strategies of abstraction. *Biology and Philosophy*. 21.5 (2006): 741-755.

So.... How to think about models?

- ~~George Box: All models are wrong, but some are useful~~
- Richard Levins: Models either enlighten or obscure[2].
- What is the purpose of the model?
- Levins: Where is the rest of the world?

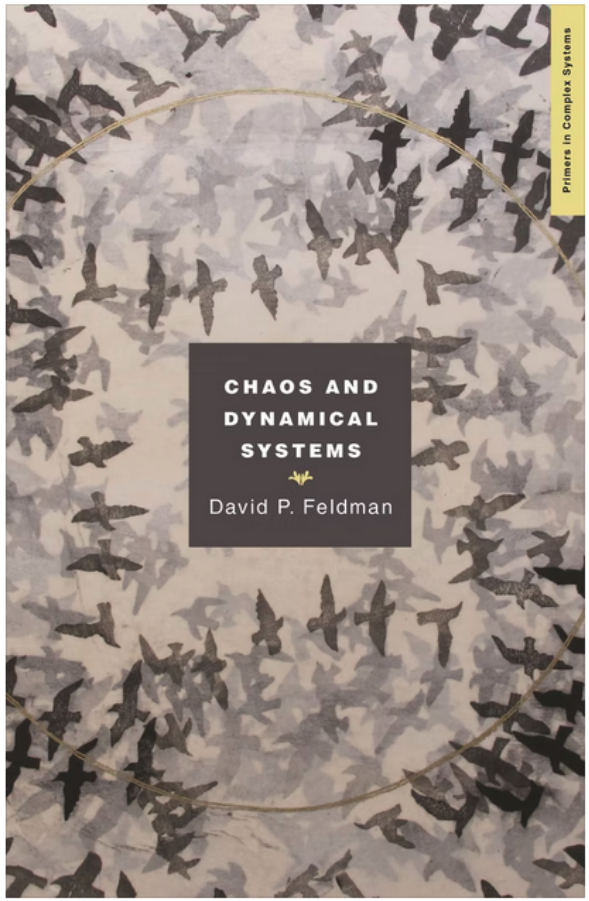
[2]Levins, Richard. Strategies of abstraction. *Biology and Philosophy*. 21.5 (2006): 741-755.

Textbook on Chaos and Fractals for Non-Majors



Feldman, David P. *Chaos and Fractals: An Elementary Introduction*. Oxford University Press, 2012.

Primer on Chaos and Dynamical Systems



Feldman, David. *Chaos and Dynamical Systems*. Princeton University Press, 2019.

Two MOOCS

- Complexity Explorer: A project of the Santa Fe Institute
- Introduction to Dynamical Systems and Chaos: `http://chaos.complexityexplorer.org`
- Fractals and Scaling `http://fractals.complexityexplorer.org`
- Around 20k enrolled, several thousand course completions.

Thanks!

- Thanks for the opportunity to present some ideas and share some of the work I've done.

- Feel free to reach out
  - `dfeldman@coa.edu`
  - `http://hornacek.coa.edu/dave`
  - Twitter: `@DavidFeldman`