Quantitative Content Survey (Calculus Topics)

Please rate each subject area on a scale of 1 to 4, 1 NEED, 2 WANT, 3 IF THERE IS TIME, 4 NO INTEREST.

Informed Consent documentation can be found here:  http://goo.gl/RzN4n

* Required

Have you read and understood the information provided above and allow your survey results to be used in research? *

☐ Yes
☐ No

Affiliation

Field? *

Research Interests/Speciality

Derivative *
rate of change, instantaneous rate of change, population growth rate, instantaneous growth rate, instantaneous velocity, tangent line at a point, slope, increasing, decreasing, velocity

1 2 3 4

NEED ☐ ☐ ☐ ☐ NO INTEREST

Second Derivative *
Rate of change of slope, greatest rate of change, concave up, concave down, acceleration, change in velocity, slowing down vs speeding up growth rate

1 2 3 4

NEED ☐ ☐ ☐ ☐ NO INTEREST
Qualitative Behavior*
Graphing solutions to differential equations

NEED   NO INTEREST

Qualitative Behavior*
Graphing functions from first and second derivative information

NEED   NO INTEREST

Exponential Function*
Exponential growth, feedback loops, positive and negative, growth rate proportional to current population size, kinetics, diffusion

NEED   NO INTEREST

Maximum, minimum,*
Global and local, maxima/minima, optimizing, objective function, biomechanics (migration, foraging, energy solutions), optimal harvesting

NEED   NO INTEREST

Implicit Differentiation*
Understanding relational change, how does total length grow with respect to carapace length

NEED   NO INTEREST

Multidimensional Calculus*
Change along a cross section, like for multidimensional surfaces

NEED   NO INTEREST

Population Growth Models*
Logistic growth, Von Bertalanffy, exponential growth, Gompertz growth, allele effect, migration, emigration, birth-death, interactions, for species of animals as well as chemicals, harvesting
Equilibrium Analysis *
Equilibria, stable state, qualitative analysis, unstable state, exponential decay to stable equilibrium, carrying capacity, exponential growth away from unstable equilibrium, snowball earth, steady state, conservation of energy, potential vs kinetic energy

Growth Models with Interactions *
2 variable differential equation models, arms race, predator-prey, coevolution, eigenvalue, matrix

Growth Models of Interactors *
Stable oscillations (predator-prey cycles), dampened oscillations, expanding oscillations, cycles, boom bust economics

Growth Models with Outside Influences *
Population and economic bust due to over harvest, tipping points, multiple steady states, equilibrium changing from stable to unstable (snowball earth, climate change), bifurcations

Growth Models with Multiple Interactors and Outside Influences *
Multivariable differential equation models, SIR disease modeling, human epidemics and zoonoses, reproductive number of disease, multiple strain or species interactions

Partial Differential Equations *
Spatial models, traveling waves of disease or invasion
### Continuous/Discrete
Continuous versus discrete models

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
|---|---|---|---|------|-------------|

### Discrete Models
Difference equations, iterations, programming, analogous growth models

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
|---|---|---|---|------|-------------|

### Discrete Model Equilibria
Equilibria in difference equations, chaos

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
|---|---|---|---|------|-------------|

### Discrete Matrix Models
Age-structured models, tree matrix models for forest health, different size plants or larvae, eigenvalues, matrices, eigenvectors

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
|---|---|---|---|------|-------------|

### Fitting Data to a Model
Log transform data, regression, exponential model fitting, model fitting

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
|---|---|---|---|------|-------------|

### Integration and Probability
Probability distribution functions, cumulative probability, integral, finite integral, approximating a finite integral, area under the curve, finding number given a density function over soil depth or water depth, sieve filtering curves

| 1 | 2 | 3 | 4 | NEED | NO INTEREST |
Integration and Physics *
Work, water, pressure, center of mass

Integration and Antiderivatives *
Analytic/Quantitative Solutions to simple growth equation models

Limits *
Limits, average growth vs instantaneous growth, carrying capacity

Computer Skills *
Excel, matlab, programming, symbolic math program, TI-83

Modeling *
Appropriate Growth and Interactions Model selection and/or development

Theory Behind Current Science *
Reading current theoretical literature

Thank you so much! Any other feedback/suggestions for content?
Never submit passwords through Google Forms.
Table S1a. Content of redesigned calculus courses at Unity College.

| UC Calculus I Topics (3-credit) | Topics in terms of biological concept | UC Calculus I Assignments (3-credit) |
|---------------------------------|--------------------------------------|-------------------------------------|
| Sequences                       | Notation, understanding of time series data |
| Linear discrete-time dynamical systems | Recursive or iterative processes, where populations reproduce or are managed in at once per time step (year or generation, etc.). Precursor to Leslie matrix models or stage-based models, where an important difference in long-term behavior/equilibrium is characterized by whether $\lambda < 1$ or $> 1$. |
| Limits and Continuity           | Long-term behavior/outcome of processes such as population growth, and relaxing assumptions to allow birth or death to happen at any time, not just once per year or generation. |
| Derivatives                     | Describing change in continuous processes |
| Exponential models with data integration and as differential equations | Describing exponential models as models in which the rate of change is proportional to the current size or per capita growth rate is constant. Applications also include Newton’s Law of Cooling, which can be used to determine animal death time to determine illegal hunting activity. |
| Modeling with 1-D ordinary differential equations | The effect that parameter $r > 0$ or $< 0$ has on long-term outcome for exponential growth, logistic growth and interpretation of $r$ and $K$, simple climate modeling, and tipping points. |
| Optimization                    | How form reflects the optimization of important functions (e.g., Why are single celled organisms often rods or spheres?). Finding optimal solutions for other situations (minimizing cost, supplies, or net energy gain). |
| Partial derivatives             | Change along a three-dimensional surface. Understanding how to talk about slope on a real landscape. Multi-dimensional applications include optimization of models with multiple parameters and sensitivity analysis, which are not covered in the class, but referenced in terms of where they will see it in other classes. |

Low-stakes reflectionary writing
Weekly practice – homework or quizzes
Group mathematical explorations
Group professional report
Group lab report
Group slide presentation
Individual presentation of research article
Computing skills: Excel and Wolfram Alpha, Google Docs/Spreadsheets
Other assessments: Two exams and a final exam, each half in-class, half take-home.
| UC Calculus II Topics (3-credit) | UC Calculus II Topics (3-credit) | UC Calculus II Assignments (3-credit) |
|---------------------------------|---------------------------------|-----------------------------------|
| Integration and series, continuous probability distributions | Finding cumulative counts under data plots, such as accumulated degree days. Also extended to approximating cumulative counts under continuous curves (such as probability distributions). Improving approximation by using smaller intervals aided by mathematical identities and computer algorithms. Connection of integration to “reversing” the process of finding derivatives. Introduces some mathematical techniques which allow us to make generalizations when the processes we are interested in have unknown parameters (e.g., solution curves of the exponential growth and the logistic differential equation). The effect parameters can have on long-term outcomes and the role of mathematical modeling in aiding intuition and ecological theory. 1-D limited growth models, 2-D predator-prey and competitive exclusion models, introduction to multi-species interactors. The goal is to introduce mathematical approaches to systems thinking. | Weekly journal article or relevant reading discussion  
Weekly homework  
Individual lab reports with peer review (Eaton and Wade, 2014)  
Individual research project with oral presentation at research conference  
Computing tools: MATLAB (with an option for R) |
| Antiderivatives and exact solutions to 1-D autonomous ordinary differential equations (ODEs) | | |
| Numerical solutions and qualitative analysis of 1-D and 2-D autonomous ODEs | | |
| UP Calculus I Topics (4-credit) | UP Calculus I Assignments | UP Calculus I (Bio) Topics (4-credit) | UP Calculus I (Bio) Assignments |
|--------------------------------|---------------------------|-------------------------------------|-------------------------------|
| Limits Continuity Derivatives | Webwork problems to test basic skills | Discrete-time dynamical systems | Reading assignments from mathematical biology literature |
| Applications of derivatives    | Written homework selected from the textbook | Limits Continuity Derivatives Applications of derivatives and dynamical systems | Reflectionary journal assignments |
| Integrals                      | • Most problems are short answer | Antiderivatives | Written homework from the textbook |
| Applications of integrals      | • Some application problems from physics and engineering; few that require interpretation of results. | Differential equations Integrals Applications of integrals and differential equations | • Few short answer problems to test basic skills |
| Antiderivatives                | Other assessments: Three exams and a final exam, all in-class; weekly quizzes | Other assessments: Three exams and a final exam, all in-class; weekly quizzes | • Majority of problems are application problems, all with an emphasis on applications to the life sciences; most require interpretation of results. |

Computing tools: Problems requiring use of Mathematica, Excel, and Geogebra to aid in model exploration
Other assessments: Three exams and a final exam, all in-class; weekly quizzes

Table S1. List of mathematics topics and types of assignments/activities in each Calculus I course at UP and in each Calculus course at UC. Table S1a presents the mathematical content, the corresponding biological interpretation/application, and the pedagogical scaffolding. Table S1b compares the traditional Calculus I course mathematics content at UP with the mathematical content of the Bio section of Calculus I at UP. Yellow highlighting indicates concepts added to the (Bio) section content list.
Table S2. Summary of DWF, withdraw rates, and adjusted CCI scores in each class at UC over 9 semesters and 13 classes. The resulting analysis of trend for DWF rates is shown in Figure 1a in the paper. The figure showing adjusted CCI results is in Figure 2. All courses during this time were taught by the co-author at Unity College. A noted difference in N for the CCI results versus the DWF rates is due to either withdrawing students (as in the case of Fall 2012) or students that did not consent to having their data used for educational research (as in Spring 2015).

| Transition Stage | Semester | DWF % (W) | N      | CCI adj. | Adoption Notes |
|------------------|----------|-----------|--------|----------|----------------|
| Before           | Fall 2010| 31% (23%) | 13     | n/a      | Traditional content 3-credit calculus course |
| Before           | Spring 2011 (2 sections) | 25, 37.5% (0, 25%) | 20.8 | n/a      | Traditional content 3-credit calculus text with some applied activities |
| During           | Fall 2011 (2 sections) | 7, 15% (0, 0 %) | 15, 20 | n/a      | Adopted new life sciences text and associated syllabus with writing integration |
| During           | Spring 2012 (2 sections) | 57, 35% (0, 12%) | 7, 17 | n/a      | Before registration for fall, new majors and requirements introduced to students – Biology dropped the Calculus I requirement, and Wildlife introduced a management track without a Calculus I requirement. The track that retained Calculus I, allowed for Calculus II to also satisfy a menu requirement in the major. |
| During           | Fall 2012 (2 sections) | 27, 30% (9, 20%) | 11, 10 | 27, 33% (N=10,8) | Existing students were still offered transition plans into majors defined in the 2012 catalog. |
| After            | Spring 2013 | 0% (0%) | 9 | 15% | Gateway exam utilized |
| After            | Fall 2013 | 19% (0%) | 16 | 14% | Gateway exam utilized |
| After            | Spring 2014 | 0% (0%) | 16 | 23% | Gateway exam no longer utilized |
| After            | Spring 2015 | 27% (N=10) | 12 | Analyzed additional CCI data to replicate “after,” but without gateway exam. Marine Biology added Calculus I to major requirements list, effective Fall 2016. |