

Teaching :: Ariel Cintrón-Arias

“Students learn in many ways— by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing and drawing analogies and building mathematical models”

Richard M. Felder and Linda K. Silverman

As an educator, I believe education is a core factor of any society. One of the most worthwhile investments a society can make is investing in education, in particular higher education. Ideally, the more members of society with college degrees the better returns the society has. I believe this is the result of the intellectual transformation individuals go through, as well as, the support system established while attending college and graduate school. This support system tends to nurture careers and becomes a core element in the decision-making process once entering the labor force.

A faculty member usually engages regularly in at least three forms of teaching: traditional teaching of courses, supervising research projects, and academic/career mentoring. Traditional teaching has well defined academic objectives. The faculty member conveys the material by:

- delivering engaging oral presentations in class;
- providing opportunities for students to interact with each other;
- answering questions during office hours;
- motivating and leading students with appropriate questions in homework assignments, projects, quizzes, and examinations.

Effective oral presentations combine lectures with active learning allowing students the opportunity to get involved with the concepts being discussed. Many tools engage students in active learning. My approaches to integrate technology for active learning and two-way communication with students include:

- *developing multi-media presentations that illustrate concepts*: this tool targets visual learners;
- *use of a course webpage in Desire to Learn (D2L)*: to post announcements, materials, the syllabus, deadlines and schedules, and to get access to additional resources such as class slides and lecture notes (developed in PowerPoint or LaTeX-Beamer);
- *use of an email-list*: to keep in touch with most of the students and brief them with tips and pertinent announcements;
- *online instructional tools*: online grading systems give immediate feedback to the students. These tools allow me to trade the time I would spend grading for additional time with my students in office hours, or preparing lecture notes and presentations. I have used the following online grading systems: WebWork, WebAssign, StatsPortal.

Mathematics majors in 2012 must develop a broad view of the interplay between computational tools and theoretical mathematics. After all we, as higher education faculty, are in the business of training a forthcoming generation of *quantitative scientists* (this is the term by which mathematicians are hired in the job market outside academia). It is important these students become familiar with:

- more than one operating system, including: Microsoft Windows, Unix/Linux, and Mac OS X;
- various packages such as Maple, Mathematica, MATLAB, Octave, FreeMat, Numpy, Sage, R, Wolfram Alpha, Minitab;
- at least one programming language such as Python;
- several text editing tools including Latex, PowerPoint, LibreOffice.

This familiarity can be achieved by integrating computer laboratories with the regular classroom meetings. Followed by assigning projects that exploit the numerical and symbolic algebra capabilities of Maple and MATLAB (or Sage and FreeMat), and require typing their solutions in Latex.

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From Fall 2009 through Spring 2012 my teaching at East Tennessee State University (ETSU) has involved courses with conventional methodology, and those classified as independent study and thesis. For example, I have taught seven different courses with conventional methodology, from 1000-level through 4000-level:

- MATH 1530 Probability and Statistics Non-calculus
- MATH 1910 Calculus I
- MATH 2010 Linear Algebra
- MATH 3150 Mathematical Modeling
- MATH 4027 Introduction to Applied Mathematics
- MATH 4267 Numerical Linear Algebra
- MATH 4257/5257 Numerical Analysis

Moreover, even though the following courses are formally classified as conventional methodology, their syllabus is more flexible and I adjust it every time I teach them:

- MATH 2390 Introduction to Research in Quantitative Biology
- MATH 4957/5957 Special topics in Mathematics

In addition, I also have taught the following courses, which are classified as independent study or thesis

- MATH 4010 Undergraduate Research
- MATH 4900 Independent Study
- MATH 5960 Thesis

In summary, I have been the instructor of record for twelve different courses at ETSU. The two courses for which I have developed the most materials are: Linear Algebra and Mathematical Modeling. I taught each of them three times.

For Linear Algebra (MATH 2010) I decided to adopt an open-source textbook: *First Course in Linear Algebra* by Robert A. Beezer. An immediate benefit for the students is that the electronic version is available to them for free. However, the cost of printing this textbook can be at least \$30. In this course my evaluation scheme has the following components: tests; assignments and quizzes; computer laboratories; final exam. I put a strong emphasis on assignments and quizzes; for example, in Fall 2011 students were given 19 quizzes. These quizzes were take-home and students could submit their answers online and received quick feedback. The contents of the Linear Algebra course I teach are divided into the following modules:

1. Systems of Linear Equations
2. Vectors
3. Matrices
4. Vector Spaces
5. Determinants
6. Eigenvalues and Eigenvectors
7. Singular Value Decomposition
8. Linear Transformations

Lecture notes, typed in LaTeX Beamer, for each module are attached. These slides are made available to the students in D2L/content every week, and they are basically transcriptions from the textbook chapters.

For Mathematical Modeling (MATH 3150) I have adopted two different textbooks in three occasions (*A Course in Mathematical Biology* by de Vries, et al.; *Mathematical Models in Population Biology and Epidemiology* by Brauer, F. and Castillo-Chavez, C.). Because I continue to search for the textbook that best fits the scope of this class. My evaluation scheme for MATH 3150 is based on the following criteria: midterm exam, final exam and projects.

When I teach this course mathematical modeling is discussed in the context of population biology, theoretical ecology, and evolutionary dynamics. These areas are closely related to my research interests. The main theme of this course is dynamical processes that evolve in time. Nearly 85% of the course material is based on deterministic modeling, but yet I do make an effort to give a broad perspective, by contrasting deterministic versus stochastic, along with models constructed with ordinary differential equations, difference equations, and partial differential equations. Numerical solution and simulation of models is another component of this course. The contents of this course are usually divided into the following modules:

1. **Exponential and Logistic Models:** Exponential growth and decay are discussed. Students use Minitab to fit data, using linear regressions to estimate parameters. Qualitative analysis of models is introduced, along with concepts of equilibrium and stability. The logistic model is derived and students use R for data fitting.
2. **Discrete-Time Population Models:** Maps and fixed points are introduced. Stability of fixed points is first discussed with cobweb analysis and then with linearization. Existence and stability of periodic cycles is also covered. Students visualize period doubling route to chaos by implementing a MATLAB script to generate orbit diagrams.
3. **Continuous-Time Models for Two Interacting Species:** Lotka-Volterra (predator-prey) models are derived from first principles. Then reaction-kinetics models are discussed with emphasis on nondimensionalization, Jacobian computation and linearization around equilibrium points.
4. **Nonlinear Dynamics and Elementary Bifurcations:** Brief review of eigenvalue and eigenvector computation. Discussion of the role played by eigenvalues in the dynamics of linear systems of ordinary differential equations. Illustration of how a linear system undergoes dynamical changes (reflected by eigenvalues) from supporting a stable spiral to a stable limit cycle to an unstable spiral. Definition of bifurcation and normal forms: saddle-node bifurcation; transcritical bifurcation; pitchfork bifurcation; Hopf bifurcation.
5. **Diffusion Processes:** Derivation of the diffusion equation from a random walk on a line. Numerical illustrations, using MATLAB code, of the normal approximation to the binomial distribution: Gaussian solution to the limiting diffusion equation.
6. **Introduction to Evolutionary Game Theory:** Introduction to elements of a theoretical game. Payoff matrices: two-player two-strategy matrix; strategy matrix. Definition of evolutionary stable strategy and derivation of replicator equations for a game with two strategies.
7. **Introduction to Stochastic Processes:** Brief review of probability. Simple birth process: derivation of underlying deterministic model; derivation of stochastic model; Kolmogorov equation; mean and variance of the process. Birth and death process: deterministic and stochastic versions of the logistic model; numerical implementations with MATLAB of both deterministic and stochastic logistic dynamics. Deterministic and stochastic versions of Susceptible-Infective-Susceptible model: illustrations with numerical simulations in MATLAB.