# Teaching statement — Alex H. Barnett, November 2013

I have unusually wide teaching experience: I bring my physics, biomedical, and computational backgrounds to bear in mathematics; I have developed several new applied mathematics courses from scratch; I receive consistently excellent evaluations at an institution that has been **ranked #1 for undergraduate teaching** for the last four years running (U.S. News and World Report); and I now co-teach our nationally-acclaimed graduate teaching seminar.

In the classroom I make learning an interactive discovery process: most of my class periods involve a 10-15 minute session where students work in small groups to solve problems on **worksheets** that I have devised. I am then able to move around the room, asking probing questions or giving hints, learning how each individual thinks. This builds their communication skills (the strong students often teach the weaker ones better than I could), while giving me instant feedback on their areas of difficulty to help me steer the lecture. The classroom buzzes with discussion—the energy level is high. Students take an active rather than passive role: by the end of lecture they have solved one or more core problems themselves, rather than merely copied down solutions from the board. I post all worksheets, and solutions, online for later study. Student feedback on the use of worksheets is *consistently* enthusiastic. My influences include working for Eric Mazur (a pioneer in peer instruction techniques), my time as a facilitator at Harvard's Bok Center, and Dartmouth's Center for the Advancement of Learning, and in observing 100 hours of teaching co-running the seminar at Dartmouth. Such peer instruction has proven successful throughout science [1], for students of different levels and styles [3], and in increasing female STEM enrollment and retention [2].

Many of my lectures feature a **live demo** with some real world object that meaningfully illustrates or brings a concept to life. For example: huge colored 'vectors' to explain cross product, using torsional wave machines for differential equations, casting shadows of solids with a flashlight (or penetrating them with knitting needles) for triple integrals, hitting drums (or whirling flexible plastic tubing above my head!) while measuring their frequency spectrum to illustrate eigenvalue problems, and bringing professional musician groups to class. I also use computer demos, for instance showing students applets that let them see vector fields using fluid flow, or have students write their own codes. I find that visualization is key to student understanding and engagement.

Since **computer programming** plays an important and growing role in applied mathematics and the sciences, I have woven a component (mostly MATLAB/Octave, but also online applets and audio analysis software) into almost every course I teach. Thus, students coming out of my courses have experience with computational tools that modern scientists use—a research and career advantage. At the major and graduate level I emphasize programming skills more strongly: students are trained on to debug their own codes, and build modular, documented routines.

In the last few years I have developed from scratch **five new applied math courses**, each of which attracts healthy enrollments. These courses greatly expand the applied offerings at Dartmouth ( the first two now form a core part of our applied math major):

- Math 46: *Introduction to Applied Mathematics*, a math- and science-major course covering core analytical tools such as dimensional analysis, perturbation series, integral equations, Green's functions, Fourier transforms, and analysis of PDEs.
- Math 53: *Chaos!*, a math- and science-major course introducing phenomena in dynamical systems (maps and flows), their rigorous analysis, numerical simulation, and applications.
- Math 56: *Computational and Experimental Mathematics*, for both pure and applied majors, bridging numerical analysis, the fast Fourier transform, spectral approximation, fast algorithms for computing millions of digits of $\pi$, and factorization of huge integers.
- Math 5: *The Mathematics of Music and Sound*, a non-science major course that fulfills the quantitative distribution requirement, covering musical acoustics, functions and signals,

Fourier analysis, waves, musical instruments, human hearing, and digital sound technology (all without calculus!)

- Math 116/126: *Numerical Methods for PDEs and Waves*, a graduate-level course on numerical analysis, scientific computing, fast algorithms and integral equations, incorporating research-level material.

I make independent **project work** a key part of assessment, sometimes replacing a final exam; students respond very enthusiastically, since now they feel ownership of the work they are doing, and experience the excitement of research. In fact, I have seen students 'pull out all the stops' when finishing projects like at no other time, and experience great satisfaction when completed. Projects have included computing Lyapunov exponents in chemical chaos, testing new numerical methods for solving 2D PDEs, and measuring the temporal sensitivity of the human ear. Often I also set up an online wiki/comments page where students can post examples of each week's material from everyday life and culture, connecting the content to applications, and providing discussion material relevant to their lives. Communication skills are assessed: I work with them to teach them how to craft engaging and clear class presentations and write-ups. I often have a final presentation evening with pizza—a mini math conference—where students learn about each other's projects, and learn how to communicate in a microcosm of a professional science community.

This spring thanks to NSF funding, graduate student Megan Martinez and I created and tested a new middle-school teaching module, *Periods, Pitches and Pipes*, connecting **music and mathematics**, including the harmonic series, computer signal measurement tools, waves, and the speed of sound. Each student calculates, builds, and performs with a set of tuned pan pipes.
See: `http://www.math.dartmouth.edu/~ahb/musicmath/`

Mathematics graduate students from Dartmouth are highly sought-after by institutions that value teaching; in large part this is due to our nationally-recognized deep **graduate instructor development**. I co-teach this course (Math 147): it includes educational psychology, learning theory, video assessments, gender/race awareness, and the creation (by the students) of two weeks of a fun math camp outreach for local high-school children.

For me, teaching does not stop at the classroom: I teach and mentor my two graduate students and two postdoctoral instructors, have mentored 17 undergraduates (including five that have or will result in senior theses, and two first-years through our Women in Science Program), and I give lectures to the JHU Center for Talented Youth.

Future goals include developing the numerical analysis and computational PDE sides of undergraduate and graduate curricula, and continuing to create and refine interactive teaching tools in all of my classes.

# References


[1] C. H. Crouch and E. Mazur. Peer Instruction: Ten years of experience and results. *Am. J. Phys.*, 69(9):970–977, 2001.

[2] E. F. Farrell. Engineering a warmer welcome for female students. *The Chronicle of Higher Education*, 48:A31, 2002.

[3] D. Johnson, R. Johnson, and M. Stanne. Cooperative learning methods: A meta-analysis. `http://www.co-operation.org/pages/cl-methods.html`, 2000. Cooperative Learning Center, U. Minnesota.