Nicholas M. Boffi: Teaching Statement

I believe that teaching is one of the most rewarding aspects of academics, and it has been a strong driving force in my desire to become a professor. At each stage of my academic career – the last two years as a Courant Instructor at New York University's Courant Institute, as a graduate student at Harvard, and as an undergraduate at Northwestern – I have had the opportunity to teach and mentor in a diverse range of contexts, which has helped me grow both as an educator and as a researcher. Below, I outline my teaching methodology by describing some representative personal experiences as a course instructor, teaching fellow, and an advisor. I conclude with an overview of some courses I am prepared to teach, and a brief description of my goal to design an integrated curriculum that ***fuses applied mathematics with modern machine learning***.

Teaching

Courses at the Courant Institute. I've instructed *Numerical Analysis* twice, and *Linear and Nonlinear Optimization* three times, counting the current semester. My responsibilities consisted of designing the course syllabi, teaching twice-weekly 75 minute lectures, designing homeworks and exams, and holding regular office hours. Both courses are medium sized, consisting of 30-40 students each year, and are thought of as rather difficult advanced undergraduate courses, covering a wide range of topics at a fairly rapid pace.

Teaching fellowships at Harvard. As a graduate student at Harvard, I served as a teaching fellow (TF) for *Advanced Scientific Computing* under Prof. Chris Rycroft twice, a TF for *Estimation and Control of Dynamical Systems* under Prof. Na Li once, and a TF for *Advanced Scientific Computing II* under Prof. Chris Rycroft once. These courses are all primarily taken by early-stage PhD or masters students, but also include several advanced undergraduates each year. My responsibilities consisted of holding weekly office hours and grading homeworks and exams. In 2016, I received a Certificate of Distinction in Teaching for my performance.

Facilitating engagement. The fast pace and breadth of topics in the courses I teach make it important to consistently check in with the students to ensure that they are following along. To facilitate this, I emphasize the importance of asking questions at all levels both in the classroom and in office hours. One strategy I've found that helps promote this environment is to take an extended pause after challenging derivations and proofs, during which I ask the room for questions. Often many students raise their hands who at first remained silent, which leads to a greater understanding for the whole room, and promotes a welcoming culture for student participation.

Building mathematical intuition. I strive to emphasize intuition, and my approach centers on guiding students to come to the answer themselves. This stems from my belief that many mathematical concepts can be distilled to a few key insights that can become obscured by technicalities. When helping students grapple with conceptual difficulties, I carefully lay out the core concepts, often by working through a simple case. An example of this took place in my office hours, where I helped a student understand orthogonal polynomials for deriving Gauss quadrature rules. I walked them through the case of orthogonalizing two vectors in two dimensions, which can be illustrated graphically. I then had them derive the general procedure for polynomials themselves, which cemented their understanding of the method.

Diverse backgrounds. Given the interdisciplinary nature of the courses I teach, I believe it is important to connect with the students and to understand their background, so I can help fill in any gaps in their knowledge. I seek to establish a strong foundation, and am encouraging to those with less preparation. In the first week of each semester, I hold an “introduction to programming” tutorial, signaling that students from all backgrounds are welcome, and that everyone will be supported to learn the material. My office hours are an open forum for questions on topics ranging from hands-on code debugging to advanced extensions of topics covered in class. Each semester, this leads to a regular group of students attending for their full duration to work on homework, discuss the course material, and for general advice on graduate school and research. These practices are validated by my teaching assessments; for instance, in a recent course, 85% of respondents felt that diverse perspectives were "very integrated" into the class, and 100% found me open to diverse viewpoints.

Personal relationships. I believe that fostering a communal and collaborative atmosphere facilitates learning, particularly in mathematics, where feelings of inadequacy and self-doubt can be widespread as students compare themselves to others. To achieve this, I strive to establish an environment in which the teacher is viewed not as a superior, but as an equal. During my weekly office hours, I make a point to ask the name of each student who comes, and to introduce myself to them personally, which I find sets a welcoming tone. My attentiveness to personal relationships has consistently been well-received by the students, and I’ve been asked by several students for a letter of recommendation after each course I’ve taught.

Receptiveness to feedback. To improve my teaching methodology, I consistently solicit feedback from my students. One method I’ve found effective is to check in with regular attendees at office hours, and to ask them how the course is going; another is to send out an anonymous survey. I find that students are often pleasantly surprised to be asked for their thoughts, and provide useful, candid advice. One example of this occurred when I first taught optimization: I originally followed the syllabus from an earlier iteration, which used separate textbooks for the segments on linear programming and on nonlinear programming. I heard from students that this was confusing, particularly given subtle notational differences between the books. In response, I re-designed the syllabus for the future, and chose a single textbook that covered both topics in a unified fashion.

Promoting engagement by connecting with research. To keep students engaged with the course material, I often link classroom concepts with current research, either by recommending relevant seminars or by discussing extensions during office hours. For example, when covering under-determined least squares in *Advanced Scientific Computing*, I gave an overview of implicit bias, a recent topic of interest in machine learning theory. This helped the students understand under-determined least squares, and also excited them about a contemporary research topic.

Mentoring

Coordinating summer research. In the summer of 2022, I coordinated the Applied Mathematics Summer Undergraduate Research Experience (AM-SURE) program at Courant, overseeing a group of ten undergraduates. To facilitate collaborative learning and open discussion, I organized bi-weekly meetings where students could present their progress and challenges, which the students almost unanimously appreciated in their final reviews. To teach the students to stay organized in their research, I had them each maintain a “lab notebook” on Overleaf, an important skill I find can go overlooked in an undergraduate mathematics education. Finally, to ensure the quality of their final department-wide presentations, I held practice sessions that involved detailed feedback and one-on-one reviews, leading to significant improvements in their presentation skills.

Mentoring Winston Liang. The most rewarding aspect of the AM-SURE program was working with individual students, and perhaps the most resonant example for me was Winston Liang, for whom I've served as a mentor during my time at Courant. I first met Winston during my numerical analysis course, when he came to my office hours to ask about research and coursework opportunities in computational math. I encouraged him to take further courses with me, and recommended him to Professor Bob Kohn, with whom he started conducting research. He was later accepted to the AM-SURE program to continue his work with Bob, which resulted in a stellar research project in the area of active matter. I wrote him a letter of recommendation for graduate school based on his performance, and he has now stayed on as a PhD student at Courant.

Mentoring Jimmy Almgren-Bell. From 2017-2019, I supervised Harvard undergraduate Jimmy Almgren-Bell through a research project focused on computational modeling of evolutionary dynamics, which culminated in a senior thesis. When Jimmy began work, he had little experience with many basic aspects of computational mathematics, such as using Linux and connecting to clusters. I taught him how to use many standard command line tools and provided him with a base simulation code, so that he could gain experience with the research process. As he progressed, I advised Jimmy on enhancing the simulation, and he implemented the *competence mechanism*, whereby bacteria exchange genetic material through their environment. He found that inclusion of competence increased the rate of adaptation within a bacterial population, and that the size of this effect could be tuned by adjusting the length of the exchanged DNA strands. Jimmy graduated in 2019 with honors, and is currently a PhD student at the Oden Institute at the University of Texas, Austin.

Coursework and future plans

Courses. I am well-prepared to teach courses at all levels, ranging from fundamental undergraduate to advanced graduate. Fundamental undergraduate mathematics classes could include linear algebra, calculus, ordinary differential equations, and partial differential equations, while courses at the advanced undergraduate level could cover topics such as real analysis, complex analysis, numerical analysis, optimization, and an introduction to dynamical systems. At the introductory graduate and advanced graduate level, I am prepared to teach courses on numerical computation, machine learning, applied stochastic analysis, convex optimization, and rigorous treatments of dynamical systems theory and mathematical control theory.

Course design. I plan to design a year-long graduate level course on machine learning for computational mathematics. The course will first cover classical linear representations in mathematics such as grid-based schemes and kernel methods, with a particular emphasis on where these methods succeed, where they fail, and why neural networks offer a possible solution. The course will then cover an introduction to neural networks for mathematicians, neural network architectures useful for scientific and mathematical problems, first-order optimization algorithms for learning, and the design of learning-based algorithms for scientific computing such as physics-informed neural networks and generative modeling algorithms. Along the way, the course will cover concepts from numerical analysis that are needed for modern machine learning but are often overlooked, such as ordinary and stochastic differential equation solvers, which arise when sampling generative models. My overarching goal is to blend concepts from numerical analysis and scientific computing with modern machine learning, so as to give graduate students an introduction to both fields: after taking the course, students will be prepared for research in the rapidly evolving area of scientific machine learning.