

Statement of Teaching Philosophy

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The fundamental tenet driving my educational philosophy is as follows:

Mathematics, and calculus in particular, serves as the **operating system** of science and engineering, in a way similar to how Windows or macOS serve as necessary platforms which computers need to function. Calculus and differential equations provide the language and concepts used to formulate most scientific laws, and make up a large component of the framework upon which much of our technological world is built. As fields of science and engineering evolve, they become increasingly reliant on mathematics to advance. It is imperative then, and increasingly important for Utah and the United States in a rapidly evolving world, that students can speak this language well, and understand and appreciate its foundational role throughout the sciences, engineering, and medicine.

Given my somewhat unusual research profile as a math professor who has been on 18 polar expeditions to conduct sea ice field experiments, I often find myself in a position to be able to challenge people's preconceived notions about what mathematicians do, that math is just not very exciting, and that all the math is known and already in books! Moreover, my mathematical work on composite materials and in particular on modeling sea ice and its role in the climate system is linked to many other fields of science and engineering, including statistical physics, materials science, electrical and mechanical engineering, biomedical engineering, remote sensing, ecology, and of course geophysics, oceanography, and glaciology. Having published in leading journals in these fields, as well as in various areas of mathematics, and having collaborated with scientists from across a similar spectrum of disciplines, I use this breadth of experience to try and make math relevant and interesting to a diverse swath of our students, and to find alternative pathways to reach students from a range of backgrounds or who may learn in different ways. It also helps me to involve undergraduates from majors across science and engineering in my research program.

Through the activities listed below, which form the bulk of my educational efforts, I strive to communicate the messages above authentically and convincingly, to trumpet the value of mathematics, and to draw as many people to it as I can, in as many ways as I can.

1. **Classes.** A hallmark of my educational career has been a long term dedication to teaching introductory math classes for scientists and engineers, and calculus in particular. Since my first year of graduate school in 1981, I have taught over 8,000 students in introductory calculus and differential equations classes at New York University, Rutgers University, Princeton University, and the University of Utah. My devotion to teaching these classes aligns perfectly with the tenet above, and my desire to help young scientists and engineers to not just survive but to thrive and enjoy the math classes required for their major. I often try to get the students thinking about something unexpected, intriguing, or curious, so that they are more open to learning about the material that follows. For example, I always bring a rubber frog to the first day of calculus class. The frog starts 2 meters from a wall, jumps 1 meter, then $1/2$ meter, $1/4$ meter, $1/8$ meter, and so on, always jumping half the distance remaining to the wall. I engage the students in a discussion and analysis of whether the frog ever reaches the wall, and typically there are quite a few students coming up after class, thirsting to know more about the dynamics of this magic frog and how it may be related to the concept of a limit, the main technical tool of calculus.

Another key component of how I approach teaching, as mentioned above, is to try and make the material *relatable*. Many students not only find math challenging but also find it difficult

to see how studying math relates to their lives and career plans, other than being an onerous requirement to be endured in pursuit of a major in science or engineering. I use examples from topics in those majors to try and communicate with the students in a language they are comfortable with and may already know pretty well. For key topics, I tend to use a *spiral* approach by laying the groundwork for later results with early, intuitive examples, like the magic frog. We then visit and revisit the central ideas numerous times throughout a semester, and from several points of view – before we formally cover the topic. As outlined in the attached syllabus from Calculus I (see “Path to success in this class.”), there are key activities that I have found play a critical role in student success. Before every exam, including the final, I post a practice exam with solutions to focus their studying on what I believe are the most important topics and problem types. I hold an evening review session before every exam to go over the practice exam and answer any and all questions the students have in leading up to the real exam.

I also believe it is important to respond to student criticism, as well as changing circumstances. For example, over the past few years I have made sure to spend more time going over homework questions and more basic examples in class, and to have the TAs take over on certain occasions to field homework and other questions. During this past semester with about 170 students in two sections of Calculus I, which was taught remotely due to COVID-19, I tried to maintain the same enthusiasm and atmosphere in my live zoom lectures that I do in person. Even though we would all love to get back to teaching in person, there are some aspects of trying to recreate the classroom experience online that provide the students with very valuable new resources. Every lecture in each section was recorded and posted, the many pages of notes I wrote on a tablet during each class were posted as pdf files (rather than erased from the board), and the review sessions were recorded and posted along with the notes I wrote during each session. Finally, toward the end of each semester I give a lecture, at the student level, about my sea ice research and its relation to calculus, including video of a recent Antarctic expedition, with penguins, killer whales, and exciting science, to demonstrate just how far math can take you!

2. **Mentoring.** During my senior year of high school in Maryland, I was mentored by Jay Zwally after school at nearby NASA Goddard Space Flight Center, where we studied satellite images of Antarctic sea ice. During my undergraduate years at Dartmouth College, I worked with Steve Ackley after classes at the nearby US Army Cold Regions Research and Engineering Laboratory, where I did research on the interaction of radar waves with sea ice, and went on my first Antarctic expedition. These early experiences, along with wonderful collaborations with my Ph.D. and postdoctoral advisors, ultimately determined the direction of my career. I have thus become particularly passionate about giving similar research opportunities to high school students and undergraduates, as well as to Ph.D. and M.S. students and postdoctoral investigators. One of the reasons I teach introductory calculus classes, in addition to then being able to encourage students to consider a math major or minor, is to recruit top talent and get them started early on research projects, and hopefully published before graduating. Several students each year usually request that I serve as their advisor on REU, UROP, ACCESS (see below), or senior year projects. I get to know their backgrounds, interests, and goals, find a project that suits them, give them resources to learn about the project, and set expectations very high. I meet with the students regularly, but also have my Ph.D. students and postdocs help in the mentoring process. I’m always on the lookout for opportunities for my research students to give talks and posters on their work, and in many cases we work toward publication. Many of these students and postdocs have assisted in field experiments on sea ice in the Arctic and Antarctic.
3. **Course development.** In 2014 I developed a course called *Mathematics and Climate*, to provide an introduction to the mathematical study of Earth’s climate system, and the conceptual tools for students to analyze and understand the changes in our environment, and their implications,

as the planet warms. I have revised and taught the class every other year since then. My idea was to have modest prerequisites of only calculus and basic differential equations to make it accessible to undergraduate majors in science and engineering, as well as to graduate students. The class has attracted students from Math, Physics, Chemistry, Biology, Atmospheric Sciences, Geology and Geophysics, and Engineering (of various types), and enrollment has grown to 24 in spring semester of 2020. In addition to developing advanced math classes such as complex analysis of several variables and percolation theory, I have also developed the materials for and given advanced undergraduate and graduate level classes in topics not typically taught in a math department, such as statistical mechanics, composite materials, and sea ice. In 2013 I helped develop the material for and was an instructor in the University of Alaska Fairbanks course on field techniques in sea ice research given in Barrow, Alaska and on the frozen Arctic Ocean.

4. **ACCESS and promoting diversity in mathematics.** Since my first formal interaction with the ACCESS program in 2016, where 25-30 incoming undergraduate women are immersed in science and math for 8 weeks in the summer before starting first year classes, I have been a big supporter (see the letter from Tanya Vickers). Ruby Bowers was assigned to me for her spring 2016 ACCESS research placement, and we began a fascinating new area of investigation into microbial habitability of the “sea ice” on the moons of Jupiter and Saturn. Several top students have since done their research placements in my group, and I have felt like a major beneficiary of this great program. Moreover, its goals and perspective resonate with my own – of getting motivated young people involved early in math-related research, and that we all benefit from and should work toward a more diverse, vibrant student body, faculty, and workforce. In my experience and from my perspective, we need more women and people of color in mathematics, and ACCESS is directly working toward this goal. Having served as research advisor to a number of female high school, undergraduate and graduate students and postdocs, I have become much more familiar with the challenges that women face in pursuing a career in mathematics and science. Hence I was immediately on board when asked in 2018 to lead development of the math component of a broadened ACCESS program with a more unified theme. For the past three years, developing the materials for and co-teaching (with Jon Chaika) the ACCESS module on *Mathematics of Climate and Energy* has been a real honor and pleasure.
5. **Educational administration.** In line with the fundamental principles of my educational activities described at the outset, I have served in a number of positions, particularly from 2002 to 2012, that enabled me to initiate the development of an applied math major, significantly expand undergraduate research activity and available funding, and help increase the number of math majors by over 50%. These positions include (see CV) Director of Undergraduate Studies, Research Experiences for Undergraduates Program Coordinator, Undergraduate Curriculum Committee Chair, Coordinator for Calculus Classes, and Engineering Math Coordinator.
6. **Public lectures and media outreach.** I have been very fortunate to have had so many opportunities, through invited lectures and presentations, to communicate broadly with the general public, groups of students of all ages, business leaders, local and national lawmakers, and scientific audiences from across many disciplines. Media interest in my work has connected me on numerous occasions with talented magazine, newspaper and web journalists, TV and radio reporters, video producers, and interviewers representing diverse audiences. Through these media interactions and public presentations, I try to use these opportunities to show how interesting and exciting math can be, to present compelling images and data on climate change, such as the dramatic loss of summer Arctic sea ice, and to tell the story of how mathematics is playing a critical role in advancing how sea ice is represented in climate models, and improving projections of the fate of Earth’s sea ice packs and the ecosystems they support.