Like many professors in San Francisco State University’s COSE (College of Science and Engineering), Dr. Arek Goetz both teaches and conducts research. Goetz, however, is so dedicated to teaching that his research is also about teaching: specifically, how to make mathematics accessible to anyone, anywhere through distance learning. While increasingly popular since the 1990s, distance learning has presented many technical and pedagogical challenges. This is particularly true for the field of math with its abstract concepts. Applying both energy and originality, Arek Goetz has created an online distance learning course in calculus that now reaches students all around the world. This innovative course has enabled hundreds to successfully learn a traditionally difficult subject with little more than a phone, a home computer, and some old-fashioned self-discipline.

Goetz identifies his primary interest in teaching as “pedagogy,” the science of teaching methods. His specialty within that broad area is developing new ways to use computers to teach mathematics. While he has taught in a traditional classroom environment for years, he considers computers to be “an important pedagogical tool in learning ... especially to allow large groups of students to access learning.”

Goetz currently teaches the online calculus class that he developed, Math 226, through the math department and the College of Extended Learning. This course overcomes the tricky obstacle of teaching each step to solving math problems while on-line rather than face-to-face. SF State may be the only university in the CSU system to currently offer an online calculus class. It invites and serves students anywhere in the Bay Area, the U.S., and beyond. It is particularly popular among students preparing for graduate studies in business, medicine, pharmacology, and biology. Some community colleges across the state do offer online math classes, but they generally cover math only through the geometry level. What’s more, they require students to come to campus on a weekly or monthly basis. Enrolling students must also purchase special computer software for submitting homework.
Goetz's Math 226 class tackles some of the biggest stumbling blocks to distance learning. In the 1980s and 1990s, distance learning involved students watching taped videos of instructional material, followed by calling the instructor to ask questions. The instructor, however, could only respond to one student at a time, and the student had no interaction with peers in the class. Getting the instructional video to students was also a problem: Students had to wait days for the video to arrive in the mail, and pay return postage. Tapes could easily be lost or ruined in transit. In addition, since the tapes arrived on different days to different students, some had an unfairly longer amount of time to work on homework.

In the early years of distance learning, the homework itself presented problems, too. Before the widespread use of computers, a student had to either bring homework to campus, negating the point of an at-home course, or mail it to the instructor despite the huge lapse in feedback time. When home computers became more commonplace in the 1990s, students could more easily submit typed homework. This doesn't work for mathematics, however, since the standard keyboard lacks even the square root sign let alone the symbols for integral and differential calculus equations.

The course Arek Goetz pioneered at SF State solves these problems with the new wave of technology that has become much more accessible in recent years. Students in his class scan or photo-copy their homework, allowing them to hand-write assignments. Twenty-six streamed on-line video lectures and 200 short video clips relating to specific homework assignments give students easy access to both the course material and the professor. Students also get equal amounts of time to work on assignments. These innovations make Goetz “one of the first professors,” in his own words, to have created “a full on-line Calculus I class with videos and with students from around the world.”

Goetz was so committed to expanding educational access to mathematics that in 1999, he moved from Boston University to SF State. “It’s a different atmosphere in San Francisco than in Boston,” Goetz explains. “Boston University, where I taught, is a private, elite school. Many of the students there are from a wealthy background, with parents and grandparents who went to college.” By contrast, Goetz says, SF State is a far more diverse learning environment. Here, he says, “We are serving a very large population of first generation students.” He saw distance learning as an avenue for teaching math to as many students as he could and for as low a price as possible.

A talent for math runs in the Goetz family. Unlike his parents and brother, however, who pursued careers in physics and engineering, Arek Goetz chose straight mathematics. “Math is the purest, most fundamental research area,” he says. “All the other sciences…have to make assumptions and simplify a world that is too complicated.” Math is a foundation for explaining the other sciences, from physics to biology, he adds. “For me, math is discovering the mind of god…I love math for the beauty in itself, and the sense that every piece fits together.”

While he appreciates math’s conceptual beauty, Goetz also values its practical applications to “real world phenomena” such as engineering and computing. This practicality explains why Goetz wants to make math as accessible as possible. “Math is very useful for going on to other fields,” he says. In 2005, the National Institute of Education conducted a study of college students' scores on graduate and professional school admission tests. They looked at 550,000 students who majored in a variety of arts and sciences over an 18-year period. The study revealed that math majors excelled on standardized tests: On the LSAT and GRE for example, math majors scored about 13 percent higher than the average, and much higher overall than those majoring in other fields. Another national survey showed that math majors earned 37.7 percent higher than English majors. Finally, a recent job-rating almanac showed that people with math-related jobs score their own career satisfaction far higher than those with business and medical-related jobs. “Math is absolutely applicable to many other fields,” says Goetz, and this is why “it is important to teach it to as many people as possible.”

In his efforts to develop better ways to teach math, Goetz built upon a childhood love of computers—a love that began when his father brought home a machine from work and the young Goetz taught himself to program it. Even at that early age, he realized that computers were more than just devices for entertainment. He wanted to use the machines to share his enjoyment of math with others. “A couple years ago,” he recalls, “I had a Masters student named Inho Choi. We studied how we could use “Mathematica” for the recognition of human gestures.” “Mathematica” is a complex program used for mathematical, computer, and engineering research that was created by Wolfram Research in 1988. Goetz and Choi used the program’s interface tools, as well as mathematical data, to define human movement and get the program to recognize these motions. They then applied this to teaching in a very clever way.
The on-line calculus class Math 226 “meets” in the homes of many students at the same time by means of Internet connections. Before a class “meets,” Goetz records himself teaching a lecture and working out sample problems on a wide, three-panelled white board. With the help of his brother, Slawek Goetz, Arek Goetz has programmed his video recorder to follow him when he teaches. It tracks his movements as he writes equations, and recognizes when he moves too far away from the center of the screen.

Even the calculus homework problems in Math 226 are creative. One features a video that Goetz took while hang-gliding. Students must use it to create an equation that explains his descent and how long it would take the pilot to glide certain distances. Problems like these show the students in a visual way how math relates to real-life phenomena.

Beyond submitting homework, all students must participate in Goetz’s on-line discussions. He sets up two forums every semester. One is on the course’s webpage through “iLearn,” SF State’s main homework and grading site. Students can post questions about their homework on “iLearn” and other students can answer them. Goetz or his GTAs will step in and type out the correct response if a student provides misleading advice or a wrong answer. These mistakes are rare, however, and for the most part, he finds that students are helpful and accurate with each other. One of his GTAs, Tatsiana Maskalevich, comments, “Goetz’s class is very well-designed. Students benefit more than in a traditional classroom setting, because here they are required to help each other, rather than to just get the teacher to help them.” “This is the future,” says Goetz, “having students help one another in an online environment.”

A second student forum is through the long-distance phone-calling service called “Skype,” which students download for free from the Internet. If a student’s computer has a microphone feature, she or he can use “Skype” as a phone. Lacking a microphone, students can use “Skype” to relay typed messages immediately back and forth between users. Goetz holds office hours on “Skype,” allowing him to guide students through math problems even when they are dozens or hundreds of miles away.

Despite the unique accessibility of Math 226, the course has a limited class size and “fills-up” every semester even with no physical classroom. “In theory, the class size is really only limited by two factors,” Goetz explains, “bandwidth and staff feedback on student learning.” The more bandwidth or data carrying capacity an Internet site has, the more people can access it at a time. If too many people try to access the site at a given time, a message can pop up saying “The bandwidth limit has been exceeded.”

Some faculty members around the country fail to recognize that traditional teaching methods are insufficient to address the needs of current and future generations, Goetz argues. “Because faculty is the last to get in touch with social media,” he says, “I feel like I have to constantly argue for the future.” Adds one graduate assistant in the online course, Tatsiana Maskalevich, “People do not like change. Some professors don’t believe in a non-traditional learning environment. Many are skeptical of the Internet as a means of education.”

Both Goetz and Maskalevich admit that “online classes are not for everyone.” Some students have a problem with the time commitment. “In a traditional classroom,” Maskalevich explains, “students have to come into class at a certain time, and turn in assignments on a set date. In [Goetz’s] class, students can do the assignment at any point during the week.” But some students procrastinate and fall behind without a teacher present to “parent” them. “Therefore, this class brings out a high level of maturity in students,” says Maskalevich. “They must learn good time management skills for themselves,” or else they drop out or fail to pass the course.

“One great thing about [Goetz’s] class,” says Maskalevich, “is that many students are in Open University, and are not necessarily even in the area. We get a lot of variety in backgrounds and ages, and it’s even more diverse that the on-campus environment of SF

To watch this video go to http://calculus.sfsu.edu/goetz/

Join Professor Goetz on his glider flight from Pedra Bonita, Rio, Brazil to the beach. While watching it try to match the graphs obtained by the GPS. Then answer the following questions:

(a) What was the total descent of the flight? How long did it last?
(b) What was the average rate of descent throughout the flight? (What are the units?)
(c) What was the maximum instantaneous rate of descent during the flight? At what time did it happen?
(d) Was there a time interval when the glider was ascending?
Dr. Goetz is an active researcher in Dynamical Systems, an academic instructor, and an e-learning entrepreneur. Goetz graduated from the University of Illinois at Chicago in 1996 with a doctoral degree in mathematics. Since then he held visiting positions at Boston University, the University of Exeter, University of Marseille, Institut des Hautes Etudes Scientifiques (IHES) in France, and Instituto Nacional de Matematica Pura e Aplicada (IMPA) in Brazil. He is a recipient of two National Science Foundation Grants for his research in Dynamical Systems with geometric singularities. He has delivered over 100 research talks at conferences and universities worldwide. Goetz is also the founder of mangoroot.com, a multimedia internet platform for communicating and learning mathematics over the Internet. Nearly 1000 calculus students located in various locations in the U.S. and abroad have used the platform to learn calculus and earn SF State course credit.

Dr. Goetz’s passion to convey mathematics to his students takes him to remote and exotic locations such as volcanoes and glaciers in Ecuador where he shoots multimedia clips which he then incorporates into calculus homework problems and other multimedia content.

From Cotopaxi, the second tallest volcano in Equador, Dr. Goetz encourages students to join him on an exciting adventure to join an online calculus course that he teaches.