Preparing Graduates for Careers in the Mathematical Sciences

NSF Programs Offer Unique Real-World Experience

By Sue Minkoff, William Menasco, Fadil Santosa, Stephen Pankavich, and Richard Laugesen

The National Science Foundation's Enriched Doctoral Training Program (EDT) endeavors to broaden career prospects for Ph.D. graduates in the mathematical sciences. The EDT projects are meant to foster collaboration between academia and business, industry, government, or non-profit spheres, thus preparing student participants to enter the workplace. In the November issues of *SIAM News*, the authors detailed the 2015 EDT projects at the University of Texas at Dallas and Princeton University. Here, they describe both the 2016 projects and a precursor award funded in 2014.

EDT: Experiential Diversity in Graduate Education

The State University of New York at Buffalo. Principal Investigator: William Menasco. Co-Principal Investigators: Bernard Badzioch, David Hemmer, Joseph Hundley, and John Ringland.

The State University of New York at Buffalo (SUNY at Buffalo) Department of Mathematics' project is entitled "Experiential Diversity in Graduate Education" (EDGE@UB). Led by William Menasco, a mathematics professor and director of graduate studies, the initiative is a collaboration between industry and academic partners. Mathematics doctoral students in EDGE@UB participate in a yearlong training program that culminates in a summer internship where students work on site with the industry partners. The EDT grant is expected to fund half a dozen students each year in two cohorts. The grant funds the training, release time from the students' spring teaching assistant duties, and the internship itself. Students are interviewed for participation in the project and paired with industry partners in the fall. During the winter session, the interns will participate in a math boot camp that introduces them to the specific mathematical tools they will implement throughout the summer months. In the spring, the students (and their faculty mentors) will use the time they would have otherwise spent as teaching assistants to begin site visits with the industry partners. And the students become full-time interns at the external partner organizations during the summer.

In addition to the student benefits, there are several possible perks for faculty. For instance, faculty mentors can develop a better understanding of the mathematics used in industry, gain exposure to new research problems that may impact their own work, and learn about industrial culture and possible career trajectories for mathematics students outside of academia. Each industry partner has a specific proposed problem suitable for EDGE@UB students. The partners and tentative problems are as follows: **(1)** IBM Buffalo Innovation Center: training of Watson; **(2)** M&T Bank: understanding behavior of homeowners with home equity lines of credit; **(3)** MOOG: improving understanding of the mathematics governing the mechanics of ball screws; **(4)** SecureRF Corporation: testing security protocols based on braid groups and finite fields; and **(5)** SUNY at Buffalo's School of Management: understanding the relationship between stochastic optimization and network outages.

EDT: Math-to-Industry Boot Camp

University of Minnesota Twin Cities. Principal Investigator: Fadil Santosa. Co-Principal Investigators: Daniel Spirn and Carlos Tolmasky.

The Institute for Mathematics and its Applications (IMA) ran its first Math-to-Industry Boot Camp from June 20 to July 29, 2016. The boot camp is designed to enhance the training of mathematics doctoral students by providing them with skills and experiences that are valuable when seeking positions in industry and business. Over 120 students from across the country applied, 32 of whom were selected.

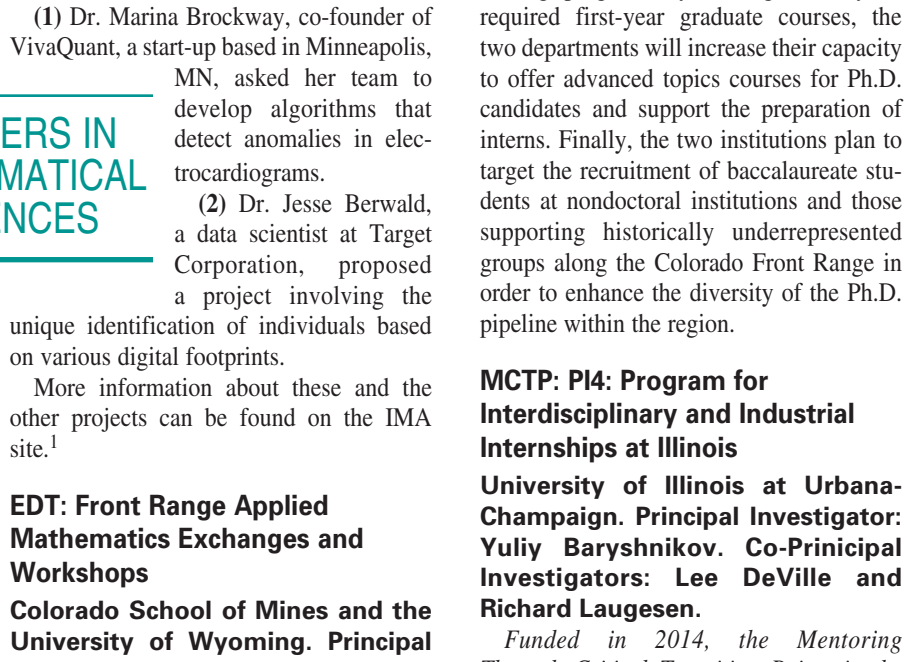
The six-week camp started with the basics of programming and utilized MATLAB, Java, and C. The second week focused on data analysis, basic statistics, and machine learning, while the third week introduced mathematical modeling, both probabilistic and deterministic. In addition to the lectures given during the first three weeks, students had hands-on sessions with COMSOL (a multi-physics solver) and the statistical package R, and worked in small groups on instructor-provided problems. During training, students acquired soft skills in teamwork, project management, meeting organization, and effective presentation techniques. They also participated in a session on resume preparation and the use of LinkedIn. In addition, mathematicians from local industries were invited to talk to students about their career trajectories, followed by Q&A sessions with the students.

During the last three weeks, students worked in teams on two projects. The first set of projects were open-ended, with the goal of having students produce a non-mathematical report and present to a group of hypothetical engineers. Industry practitioners posed the second set of projects, and each team had 10 days to determine the best possible solution and present their results. The proposers were available throughout the period as mentors, and students utilized many of the tools introduced at the beginning of camp while searching for solutions. Though the projects came from different sectors of industry, many involved data analytics. Former IMA postdoctoral fellows proposed two projects in particular:

(1) Dr. Marina Brockway, co-founder of VivaQuant, a start-up based in Minneapolis, MN, asked her team to develop algorithms that detect anomalies in electrocardiograms.

(2) Dr. Jesse Berwald, a data scientist at Target Corporation, proposed a project involving the unique identification of individuals based on various digital footprints.

More information about these and the other projects can be found on the IMA site.[1]



A fourth-year Ph.D. student at the Colorado School of Mines presents a seminar about her summer internship research at Los Alamos National Laboratory to incoming Ph.D. students. Photo credit: Stephen Pankavich.

CAREERS IN MATHEMATICAL SCIENCES

EDT: Front Range Applied Mathematics Exchanges and Workshops

Colorado School of Mines and the University of Wyoming. Principal Investigators: Stephen Pankavich and Gregory Lyng. Co-Principal Investigators: Barbara Moskal and Myron Allen.

The Front Range Applied Mathematics Exchanges and WORKshops (FRAMEWORK) program is a collaborative project between the Department of Mathematics at the University of Wyoming (UW) and the Department of Applied Mathematics and Statistics at the Colorado School of Mines (CSM). It is designed to broaden and enhance the training of doctoral candidates in the mathematical sciences by providing students with skills and experiences that are crucial for obtaining positions within business, industrial, and national laboratory settings. In order to achieve these goals, the project focuses on four key elements. First, students will participate in summer internships at national research institutions, including Los Alamos National Laboratory, Sandia National Laboratories, the United States Geological Survey, the National Renewable Energy Laboratory, and the National Center for Atmospheric Research, as well as at industrial partners such as Neptune and Company, the Western Research Institute, and the numerous technology companies located at the Wyoming Technology Business Center. These internships will introduce current Ph.D. students to real-world applications and cultivate awareness of the communication, budgeting, and project management skills necessary within professional settings. Secondly, the project will feature annual end-of-summer workshops to enhance incoming Ph.D. students' success in the first-year curriculum and showcase the previous cohort's internship experiences. To further integrate and advance student development, UW and CSM have begun an innovative course-sharing program; by sharing delivery of required first-year graduate courses, the two departments will increase their capacity to offer advanced topics courses for Ph.D. candidates and support the preparation of interns. Finally, the two institutions plan to target the recruitment of baccalaureate students at nondoctoral institutions and those supporting historically underrepresented groups along the Colorado Front Range in order to enhance the diversity of the Ph.D. pipeline within the region.

MCTP: PI4: Program for Interdisciplinary and Industrial Internships at Illinois

University of Illinois at Urbana-Champaign. Principal Investigator: Yuliy Baryshnikov. Co-Prinicipal Investigators: Lee DeVille and Richard Laugesen.

Funded in 2014, the Mentoring Through Critical Transition Points in the Mathematical Sciences (MCTP) program predates the EDT program but provides similar training to students and postdoctoral researchers in the mathematical sciences.

The employment bottleneck is particularly severe in academic mathematics, while at the same time scientific and engineering fields increasingly need researchers with strong mathematical and quantitative backgrounds. These trends create an opportunity for the development of truly interdisciplinary mathematicians – those who obtain Ph.D.s in core mathematical fields, but whose careers take place outside of an academic mathematics department. The Program for Interdisciplinary and Industrial Internships at the University of Illinois at Urbana-Champaign,[2] supported by the NSF's MCTP award, responds to this opportunity by connecting Ph.D. students from all areas of mathematics with internships in scientific labs, government labs, and industrial research groups. Program components include academic-year topics courses (e.g., "Top Ten Algorithms"); a Computational Mathematics Bootcamp to begin the summer; working groups for beginning students on exploratory topics such as "topologically constrained problems of statistical physics"; and summer internship placements for 10-12 Ph.D. students. Past projects have included a logic student analyzing patterns in fMRI data, a number theorist modeling ant colonies, a

Students working on team-building exercises during the IMA Math-to-Industry Boot Camp. Photo credit: Rebecca Malkovic.

[1] https://www.ima.umn.edu/2015-2016/SW6.20-7.29.16

[2] https://pi4.math.illinois.edu

differential equations student working in agricultural data analytics, and a topologist developing tools for augmented reality and virtual meetings. The funding from NSF has successfully catalyzed relationships with companies and government labs, and the internship program will continue to thrive beyond the grant-funded period.

Sue Minkoff is a professor in the Department of Mathematical Sciences and an affiliated professor in the Departments of Geosciences and Science/Mathematics Education at the University of Texas at Dallas. She started the Careers in Mathematical Sciences Column for SIAM News in 2010. This article (her 24th column), marks the end of her time as column editor. William Menasco (menasco@buffalo.edu) is a professor of mathematics at The State University of New York at Buffalo. Fadil Santosa is a professor of mathematics at the University of Minnesota and director of the Institute for Mathematics and its Applications Stephen Pankavich is an assistant professor in the Department of Applied Mathematics and Statistics at the Colorado School of Mines, where he has been instrumental in recruiting and advising new Ph.D. students and increasing the proportion of women and minorities enrolled within the Ph.D. program to over 60% of the graduate population. Steve has also served as the treasurer for the SIAM Central States Section since 2014. Richard Laugesen has taught at the University of Illinois, Urbana-Champaign since 1997, where his research focuses on partial differential equations and spectral theory. As director of Graduate Studies, he promotes mathematical careers in industry and government and works toward a future in which more women and minority students will pursue graduate-level mathematics.