

The REU Program at DIMACS/Rutgers University

Brenda J. Latka and Fred S. Roberts

1. Introduction

DIMACS, the Center for Discrete Mathematics and Theoretical Computer Science, headquartered at Rutgers University, runs a unique and pioneering REU program with both domestic and international components. Traditional themes of the domestic program are discrete math and theoretical computer science with considerable emphasis on applications. However, the program also has an academic-industrial co-mentoring component, a component sponsored by a new Department of Homeland Security Center for Dynamic Data Analysis headquartered at DIMACS, and a shared component with the Rutgers Mathematics Department that encompasses a wide variety of other mathematical topics. DIMACS has run its domestic REU program since 1993 under NSF support. For seven years the DIMACS REU has been totally integrated with that of the Rutgers Mathematics Department, expanding the scientific scope and student experience of both programs.

Since 1999 the DIMACS REU has had an international element co-sponsored by DIMATIA, the Center for Discrete Mathematics, Theoretical Informatics, and Applications, a distinguished research center based at Charles University in Prague, Czech Republic. This was a pioneer in international REU programs. The joint international program includes outstanding Czech students with strong European training, gives U.S. students a global international perspective, and introduces them to the mathematical sciences as a global endeavor.

The REU program has almost 30 students per year. Students from across the U.S. participate in the 8-week domestic component at DIMACS or the Rutgers Mathematics Department, with academic mentors or academic and industrial co-mentors; or in the first 7 weeks of the domestic component with an additional 3 weeks at DIMATIA. Students from the Czech Republic participate in the first 7 weeks of the domestic component and then act as hosts at DIMATIA to the U.S. students. More details of our program can be found at the DIMACS REU website, <http://dimacs.rutgers.edu/REU>.

2. Overview

The goal of our program is to provide participants with an exciting research experience that will help them decide on future educational and career paths and

Received by the editor December 27, 2006.

give them the confidence to pursue their choices. All students, including those only in the domestic component, get a taste of the international scientific enterprise. The U.S. students going to Prague get a more direct international experience and benefit from the scientific atmosphere at an international center of research. The Czech students benefit similarly from exposure to their U.S. counterparts and contribute to providing the global perspective that we seek. All students are exposed to the industrial research environment, providing a broadened view of career possibilities.

Our REU program is unique because it is run in the context of two major research centers with many scientific activities and long-standing relationships with industrial partners. The richness of the intellectual community, the synergy of the academic and industrial collaborations, and the international flavor contributed by the many foreign scientists participating in DIMACS and DIMATIA activities at the same time as the REU students adds to the overall atmosphere.

DIMACS was founded in 1989 as an NSF “science and technology center” and is a consortium of Rutgers, Princeton, AT&T Labs-Research, Bell Labs, NEC Laboratories America and Telcordia Technologies, with partners at Georgia Tech, RPI, Stevens Institute of Technology, Avaya Labs, HP Labs, IBM Research, and Microsoft Research. Undergraduate research has been a major focus of DIMACS programs since its founding. For more about DIMACS, see <http://dimacs.rutgers.edu>.

3. Nature of Student Activities

3.1. The Program at DIMACS. The key to our REU program is the one-on-one research experience under the direction of a mentor. The domestic component begins when the students arrive at Rutgers in mid-June, move into campus housing, and receive offices and computer and library accounts at DIMACS. A graduate student coordinator introduces them to their mentors to begin a program of directed study and research, including regular student/mentor meetings.

There are regular lunches and evening social activities, to which the mentors are also invited, as well as a weekly REU Seminar Series featuring local speakers and renowned outside speakers, at least one devoted to a presentation about careers and graduate school and another to developing good technical communication skills, including writing abstracts, making presentations, and developing project websites.

Students make two presentations about their projects. Early on, each describes their research problem. These short talks encourage collaboration and discussion and provide students the opportunity to work on multiple projects or even switch projects. Near the end of the domestic component, students make second short presentations about their work to the DIMACS community. Those going to Prague repeat these presentations there and make further presentations before they depart. In addition, students are asked to prepare project websites.

We introduce the students to industrial research by making trips to our industrial partners for tours and technical presentations. The students in the academic-industrial component of our program meet regularly with their academic mentor and at least once a week at DIMACS with their industrial mentor. At the industrial locations, these students are introduced to other researchers and projects. The academic-industrial co-mentoring broadens all the students’ views of the applications of computer science and mathematics.

REU students are invited to participate in the wide variety of summer programs at DIMACS. This includes tutorials and workshops in the DIMACS “Special Focus”

programs such as Computational and Mathematical Epidemiology, Communication Security and Information Privacy, Computation and the Socio-Economic Sciences, Information Processing in Biology, and Discrete Random Systems.

Students benefit from discussions and collaborations with researchers, postdocs, and graduate students who are not their official mentors and are able to switch projects or engage in more than one. It is not unusual for a student to work on a problem under the direction of a visiting researcher from a foreign country or start on a theoretical problem in computer science and end up working on an applied problem in engineering or biology, or vice versa.

After the DIMACS summer, students are encouraged to stay in touch with their mentors and enhance their project websites. Some prepare a research paper or give a presentation at a scientific meeting. Student papers are published in the DIMACS and DIMATIA technical report series and in journals or conference proceedings. Many students present talks back at their home institutions and others make their REU project a major piece of their senior thesis or eventually of a master's thesis.

3.2. Research Areas. The REU program focuses on the common strengths of DIMACS and DIMATIA in discrete math and theoretical computer science and their applications, natural areas for undergraduate research, with topics from such areas as graph theory, computational geometry, logic and complexity theory, and combinatorial optimization. Specific topics include variants of graph coloring, evolution of massive graphs, extremal combinatorics, finite geometries, new complexity classes, algebraic models of computation, large-scale linear and integer programming, binomial proportions, and statistical models of uncertainty in data streams. We also build on the interdisciplinary strengths of DIMACS and DIMATIA faculty, to include topics in DNA topology, biomedical engineering, epidemiological modeling, economic applications involving e-commerce, sensor location, information management in massive data sets, and network analysis, to name just a few. The joint program with that of the Rutgers Mathematics Department allows inclusion of a wide variety of mathematical topics involving PDEs, ODEs, commutative algebra, numerical analysis, mathematical physics, and topology/geometry.

The new Homeland Security Center at DIMACS allows us to provide an REU experience in topics such as pattern detection from multiple information sources, bioterrorism event detection, and port of entry inspection algorithms. This phase of the program exposes all students in our REU to homeland security applications and provides them with an opportunity to interact with visitors from DHS and national labs such as Lawrence Livermore, Los Alamos, and Sandia.

3.3. Social and Community Building Activities. Throughout the summer the students are invited to participate in planned group social activities. There is an orientation dinner, and other informal meals such as picnics or barbecues during the first week of the program to encourage students to mingle and meet. Lunches and dinners involved with the seminars, workshops, and field trips give the students additional opportunities to interact. In Prague, the students join faculty at lunches, are hosted by the Czech students at dinners, and go on cultural excursions organized by the Czech students.

3.4. The Program at DIMATIA. The goals of the experience in Prague are different from those for the experience in the U.S., and center around introducing the participating students to a wealth of open problems and questions and appropriate problem-solving techniques and strategies.

The Czech REU students make informal presentations while at DIMACS, preparing the U.S. students for life in Prague, and then act as hosts for the 3 weeks the U.S. students are in Prague. The U.S. graduate student coordinator and sometimes a DIMACS faculty member accompany the group. The arrival in Prague is timed to occur the week before the annual Prague Midsummer Combinatorics Workshop.

During the first week, there are tutorial presentations by DIMATIA faculty as an introduction to their scientific interests, to prepare students for the topics of the Midsummer Workshop, and to present potential research problems. Background material for these presentations is based on lecture notes from the DIMATIA “Spring School on Combinatorics.” There are presentations orienting the students to the culture and history of Prague and the country, with special emphasis on the rich Czech mathematical tradition. The U.S. students make presentations about their domestic REU research. The faculty members presenting tutorial lectures act as mentors to the students. We let the emphasis on problem solving lead to natural connections between students and mentors.

The REU students participate in the informal problem sessions of the one-week Prague Midsummer Workshop and some give research presentations at the workshop. The U.S. and Czech coordinators/mentors lead discussions on workshop topics, helping students focus on research problems. Group meetings emphasize approaches to unsolved problems, problem-solving strategies, and group attacks on problems. Students are encouraged to explore, in collaboration with Czech mentors and students, the research questions that arise during the visit to Prague and to pursue the research project begun at DIMACS with Czech mentors.

After the Midsummer Workshop, the program concludes with more intensive one-on-one sessions between students and mentors, group meetings for problem-solving, and presentations of research. While the short visit in Prague doesn’t give students as much time as they had at DIMACS to get deeply into research, the experience teaches them how research questions are formulated and pursued and enables them to make a good start on research they can pursue after leaving Prague. They are encouraged to remain in contact with their Czech mentors.

3.5. Selection of Mentors. Mentors who are able and willing to inspire undergraduate students are a key element in the success of an REU program. Mentors are invited to participate early in the Fall semester based on previous success in the program, reputation for research with undergraduates, accessibility of their research, and enthusiasm for the program. Our mentors come from a wide variety of departments besides mathematics and computer science, including operations research, statistics, chemistry, industrial engineering, biomedical engineering, and library science. This leads to a variety of project topics, which we believe is one of the primary attractions of our program.

4. Student Recruitment and Selection

The REU website serves as a primary source of information about the program and application process. We also send out paper flyers. Our mailing targets “elite” universities, minority institutions, and those with little opportunity for undergraduate research. Surprisingly, students from “elite” schools often tell us they don’t have opportunities for research. We make a special effort to recruit U.S. participants from members of groups historically under-represented in the sciences. Our mailing list has been compiled from many years of experience in running programs aimed at under-represented groups, and through our connections with professional

organizations devoted to enhancing the involvement of minorities and women in Mathematics and Computer Science.

The application for U.S. participants is web-based. The first round of acceptances is usually sent out by February 15 in order to allow sufficient time for students in the international program to obtain passports and make other preparations for international travel. The program is highly selective. The main criteria we use in selection are readiness to undertake a research project and good match of interests with a mentor. After that, we seek a diversity of participants in terms of gender, ethnicity, geography, and types of institutions they represent. Opportunities to continue their project at their home institution are considered. Usually, we give priority to students entering their senior year. For the Prague program, we select students whose backgrounds and interests and U.S. project seem to make them good candidates for success in the Prague program. Projects proposed by mentors are described on our website, applicants rank their choice of projects, mentors select students, and we put the mentor and potential student in contact.

Our advertisements and recruitment build on things that students have reported as attracting them to our programs: DIMACS reputation as a major research center; careful advance presentation of projects; the quality of the faculty mentors; the opportunity to explore the potential for graduate study in numerous fields; and the interdisciplinary opportunities available at DIMACS. Of course, the international aspect of our program is also a major attraction.

5. Closing Remarks

The DIMACS REU program provides both a scientific and a cross-cultural experience. In addition to the scientific papers and talks by our students, there is networking among the students, domestic and foreign, that we have seen last far into the future. Based on our experience, the program greatly influences the choices about further education and future careers of the students involved, and gives them the confidence to pursue their choices. With a few years experience, students develop a better understanding of the impact of the REU on their careers. We recently completed a survey of students who went through our REU programs from 1993 to 2005. A question about their advanced degree plans or achievements provided a remarkable result: 100% of the respondents had either achieved, were currently in, or were planning to attend graduate school in the near future. In almost all cases this was for a Ph. D.

Students returning from our programs in the last four years have made over 40 presentations in a variety of venues, from high schools to international research conferences, and have published a variety of papers as technical reports or in journals or conference proceedings, some solving well-known open problems and others describing new approaches to applied questions. They have won recognition such as first place in the ACM student research competition, prizes for poster presentations at the MAA/AMS Joint Meetings, the Alice T. Schafer Mathematics Prize for excellence in research by the Association for Women in Mathematics, and “best student paper” awards at the MAA national meeting “Mathfest.” The words of some of our prior program participants sum up the essence of the DIMACS program.

“REU has given me the chance to get to know people who really want to make a difference in math and science and I feel that has helped me see my capability to succeed in math research. The weekly seminars I attended offered an insight

into the numerous applications of math. The lectures on grad school were very informative because I learned about fellowships I can apply for and strategies for applying. The faculty at Rutgers University is incredibly helpful. My mentor and other professors took the time to thoroughly answer my research and grad school questions. The DIMACS faculty made me feel like they truly care about helping me succeed. This program was a great experience for me because not only did my research project teach me a lot, I also made many good friendships with the other REU students. I think it will be very interesting to see where my fellow REU friends go in the future and know that this summer at Rutgers had a huge influence on our decisions. I am forever grateful for having the opportunity to participate in the REU program at Rutgers University this summer. Thank you!" (REU 2006)

"I really appreciated the fact that this REU included such a range of projects, from the very theoretical to the very applied. ... I also appreciated how large the REU was, giving me a chance to meet a lot more of the people I'll no doubt run into in grad school or at conferences in the future ... The opportunity to go to Prague was what made this REU my top choice, I like to travel, and it was great to meet and work with students from the Czech Republic, to get a new perspective on life in general and mathematics in particular. ... I thoroughly enjoyed my project and plan to keep working on it next year, my mentors were wonderful, and best of all—I got paid to do mathematical research!" (REU 2006)

"The Rutgers program was in many ways a fantastic experience for me. ... The environment was very relaxed, but people there loved math and wanted to do good research, and so the environment was mathematically very rich. The program made a life in math research seem really enjoyable. I made a lot of good friends that I stayed in touch with afterwards. ... I still remember the REU as making life in math research seem interesting and superfun, and I think I've definitely been influenced by the exposure to the bright mathematical minds (...) I encountered at Rutgers...I was selected for a NDSEG math fellowship and a Stanford SGF fellowship ... and I think the Rutgers program had a lot to do with that." (REU 2002, 2003)

"The REU program was a unique experience in my life. It helped (me) to realize what I want to do in my life as well as got (me) into contact with leading experts in the area. A fruitful and abundant cooperation between DIMACS and DIMATIA centers is a great opportunity for students both from the U.S. and the Czech Republic to meet and work with experts from both the institutions. I think the REU program in its current form allows both the U.S. and the Czech students to meet different cultural environments and leads to a better understanding of different styles of life in the U.S. and in Europe. In the current world, this becomes very important. ... In the current world, I think it is impossible to conduct a research in the area of mathematics or computer science without a close and intensive international cooperation." (Czech participant)

"At the REU I first learned about many fields of math and computer science that I had not seen in my undergraduate studies. And, I believe I may have never learned about had it not been for the REU. I had wonderful mentors, ..., who taught me many things including how to do research. I was excited about the chance to participate in an REU again, and last summer I taught a two week course at the University of Chicago REU. I advise many undergraduates to consider

REU programs and I always suggest considering DIMACS.” (REU 1998, 1999, and currently an L.E. Dickson Instructor at U. of Chicago)

DIMACS, RUTGERS UNIVERSITY, 96 FRELINGHUYSEN ROAD, PISCATAWAY, NJ 08854

E-mail address: `latka@dimacs.rutgers.edu`, `froberts@dimacs.rutgers.edu`