

Final Report from VIGRE Grant DMS-9810726 University of Washington

The Departments of Applied Mathematics, Mathematics, and Statistics of the University of Washington were jointly awarded one of the first VIGRE grants, entitled “Integration of Research and Education in the Applied and Computational Mathematical Sciences”. Denoted NSF Grant DMS-9810726, the total award amount was \$2,510,800, with supplements of \$91,476 for curriculum development, \$147,910 for outreach, and \$109,308 for an increase in graduate fellowship stipends in years 4 and 5. The award period was from September 1, 1999 to August 31, 2004, with an unfunded year’s extension to August 31, 2005. The PIs on this grant Loyce Adams, Anne Greenbaum, Peter Guttorp, and Randall LeVeque. Loyce Adams in Applied Mathematics served as VIGRE Director for the first three years of the grant; Douglas Lind in Mathematics took over for the final two years of the grant.

VIGRE support has made a significant impact on the three departments involved in this endeavor:

- The number of majors in the mathematical sciences has dramatically increased.
- The graduate programs in the mathematical sciences have grown in both size and quality.
- Undergraduate research projects, some with industry, have been initiated in all three departments.
- Communication among our departments has improved substantially, particularly at the graduate level, and cross-departmental committees of VIGRE fellows and postdocs are helping to run the VIGRE program.
- The VIGRE program has grown from one focusing only on applied aspects to one encompassing all aspects of the mathematical sciences.
- Panel discussions on job interviews (for graduate students) and on graduate studies (for undergraduates) have been a success.
- The curriculum has been reformed at both the undergraduate and the graduate level in all departments.
- K-12 outreach activity has increased in all departments.

1. IMPROVEMENTS TO THE ACMS UNDERGRADUATE PROGRAM

A key feature of this grant was the *horizontal* integration achieved across departments by use of our Applied and Computational Mathematical Sciences (ACMS) degree program. VIGRE has been crucial in strengthening, enriching, and broadening the ACMS program, which has now grown from zero to around 160 majors. In describing the results achieved from our VIGRE grant, it is therefore convenient to start with the ACMS program.

The BS degree in Applied and Computational Mathematical Sciences (ACMS) was introduced Autumn Quarter, 1997. It was jointly developed and is administered by

the departments of Applied Mathematics, Mathematics, Statistics, and Computer Science and Engineering.

ACMS students take a set of common core courses to provide them with a solid foundation, from which they can pursue one of eight “tracks” or pathways of specialization. The program core includes the standard courses in calculus, linear algebra, differential equations, and computer programming, as well as courses in numerical methods, discrete modeling, continuous modeling, and probability and statistics. Currently there are eight pathways (see the ACMS web site <http://www.ms.washington.edu/acms/> for details):

- Biological and Life Sciences
- Discrete Mathematics and Algorithms
- Engineering and Physical Sciences
- Mathematical Economics
- Operations Research
- Scientific Computing
- Social and Behavioral Sciences
- Statistics

With VIGRE support, some of the pathways have been reorganized, and some new ones introduced such as one in Mathematical Economics (working closely with the Economics Department). Anne Greenbaum, Randy LeVeque, and Tim Chartier (a VIGRE postdoc) produced new case studies for the discrete modeling courses. Materials developed by Ka-Kit Tung for continuous modeling are being published as a book by Princeton University Press.

A key feature of the program is the Friday afternoon ACMS Seminar, which students may take for credit. This seminar offers undergraduates, as well as VIGRE fellows and other graduate students, a wide view of the mathematical sciences and has proved to be an excellent method for horizontal integration. VIGRE postdocs and fellows have given talks in this seminar, undergraduates supported by VIGRE have described their research projects, and outside visitors have shown students how mathematics impacts the real world. Some impression of the broad sweep of topics covered in the ACMS seminar can be gleaned from the web site.

2. MORE MAJORS IN THE MATHEMATICAL SCIENCES

A striking event of the past few years has been a dramatic increase in the numbers of undergraduate majors and degrees awarded in the mathematical sciences (Figure 1).

The ACMS program was designed in part to replace the “Mathematical Sciences” option for the Bachelor of Sciences in Mathematics degree, which accounted for approximately half of all majors in the Mathematics Department. The Department of Statistics initially planned to phase out its BS in statistics in favor of the Statistics pathway within the ACMS program. As these options were phased out, we anticipated a decrease in the numbers of Math and Statistics majors. This did occur as the number of ACMS majors climbed. However, during the period from 2000 to 2004 the total numbers of majors in *all three programs* have increased dramatically. As Figure 1 shows, during the period of the VIGRE grant, the number of undergraduate degrees awarded in the mathematical sciences has increased by about 50%. Since approximately 95% of undergraduate majors in the mathematical sciences are US citizens or permanent residents, this represents a dramatic increase in the number

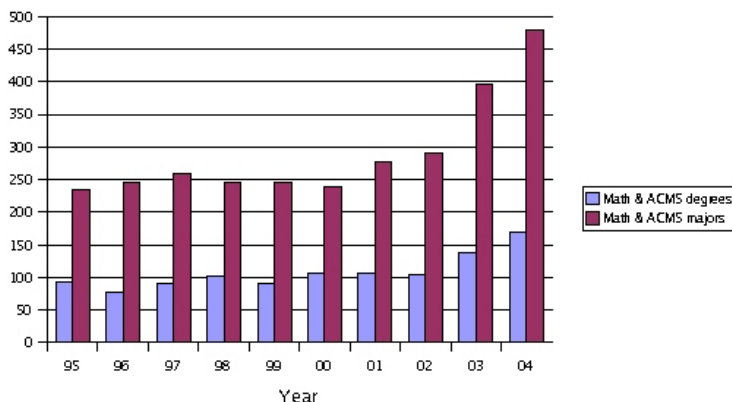


FIGURE 1. Number of undergraduate majors and degrees in the mathematical sciences at the University of Washington.

of US citizens majoring in the mathematical sciences over the period of the current VIGRE grant.

The ACMS program, in which VIGRE has played a substantial role, accounts for much of this increase. The serious and sustained efforts in revising our first-year calculus course and other changes to our courses in the mathematical sciences have made majoring in the mathematical sciences much more attractive. One external verification that our efforts have been recognized was the awarding in 2005 of the University-wide Brotman Award for Instructional Excellence to the Mathematics Department. A recent article by our University President Mark Emmert about the dramatic improvements in the UW's educational mission in the mathematical sciences can be found at

<http://www.washington.edu/alumni/columns/sept05/president.html>

Our programs attract some of the most talented students on campus. Since 1999, our students have won a number of awards, including two President's Medals (the University's highest honor for a graduating senior), a Goldwater Scholarship, two NSF Graduate Research Fellowships, three teams designated Outstanding Winners of the COMAP Mathematical Contest in Modeling: the Society for Industrial and Applied Mathematics (SIAM) Award, the Mathematical Association of America (MAA) Award, and the INFORMS (Institute for Operations Research and the Management Sciences) Award. Most recently, Eliana Hecter, a Math major whose project in mathematical biology had received VIGRE funding, was awarded a Rhodes Scholarship to study at Oxford.

3. UNDERGRADUATE RESEARCH PROJECTS

Using VIGRE funds we have substantially increased the number of undergraduates involved in projects, often in teams with faculty, graduate students, and sometimes postdocs. Well over 50 undergraduates were supported by the VIGRE grant. A recent trend is that more faculty in the Mathematics Department have been supervising

such projects. Here are a few examples to illustrate the variety of projects and the participation of both regular faculty and VIGRE postdocs in our three departments.

A team of two undergraduates (Caleb White and Youngbae Lee) worked with a graduate student (Yoonsoo Kim), Patrick Perkins (the director of the UW Math Study Center) and Rekha Thomas (Mathematics) on a project using integer programming to improve the scheduling of tutors in the Study Center, resulting in a research paper. The students developed the models, devised computational tests comparing their methods with earlier heuristics, did the analysis, and wrote the paper.

Tim Chartier, a VIGRE postdoc in Mathematics, worked on four separate undergraduate projects during his tenure here at the UW. For instance, Chartier worked with Reuben Fries to develop an applet to demonstrate the card shuffling result of Bayer and Diaconis; the applet is used in the Discrete Modeling course for the discussion of shuffles. His work with undergraduate Miranda Antonelli on multigrid methods for immersed interface problems has resulted in a paper that has been accepted for publication in *International Journal of Pure and Applied Mathematics*.

VIGRE funds supported two different teams under the direction of Nathan Kutz (Applied Mathematics). In one example, a collaborative effort in modeling the dynamics and stability of a Bose-Einstein condensate trapped in a periodic potential included a VIGRE postdoc (Deconinck), a VIGRE graduate student fellow (Patterson), and a VIGRE supported undergraduate (B. Warner). In a second example, two VIGRE graduate fellows (A. Kim and D. Yong) worked in conjunction with a VIGRE supported undergraduate (K. Spaulding) to model the behavior of pulsed light in a ring laser cavity.

David Hiller (undergraduate, Mathematics) joined the Spectral Methods research group in the winter quarter of 2003, with support from VIGRE. The group is lead by Marina Meila (Statistics), and also includes the graduate students Deepak Verma (Computer Science), Liang Xu (Mathematics), and Qunhua Li (Statistics). Hiller worked on methods to measure how “well clustered” are the elements of a given vector, a problem of central interest in spectral clustering. Hiller’s work continued this summer, supported by the University of Washington NASA Space grant.

These projects complement the summer REU program on Inverse Problems run by Jim Morrow (Mathematics) since 1988. Until the summer of 2002, nearly all of the support for this program came directly from the NSF REU grant. In the summer of 2002, the VIGRE program supported an additional student, two full-time undergraduate assistants, and a half-time faculty member. In 2003 and 2004, the VIGRE program supported three students, two full-time undergraduate assistants, and one half-time assistant. The assistants are alumni of the program and know how to work with the REU students, helping them with mathematical ideas, answering questions about Latex and computing, taking meals with the students and interacting with them day and night. Everyone connected with the REU program has said that the last two years have been phenomenal. The difference has been the VIGRE support.

The REU program has had a marked effect on the students. As we mentioned above, in the last two years the University of Washington has had three teams of

students win the MAA, SIAM, and INFORMS prizes in the Mathematical Contest in Modeling. This is without precedent. Six of the seven team members were alumni of the REU program (there is some overlap on the teams). The REU program successfully trained them to state, analyze, and solve difficult problems. The REU students are winners of NSF Fellowships, Goldwater Scholarships, graduate school awards and some have gone on to faculty appointments at universities such as UCLA, MIT, and NYU.

4. SUCCESSFULLY MENTORED VIGRE POSTDOCS

Each department successfully mentored its VIGRE postdocs.

Lisa Korf (Mathematics, 1999–2002), whose specialty is Optimization, is active in a number of outreach activities. Since 1999, she has served as a mentor for the UW WISE (Women in Sciences and Engineering) program, and has participated in the PIMS Modeling and Industrial Problem Solving Workshops held at UVic and UW in 2001, and other activities. Korf was the faculty mentor of an Applied Mathematics graduate student on a project at Boeing. At the end of her VIGRE appointment, she was hired by the UW Mathematics Department on a tenure-track position. She is the recipient of an NSF grant in Applied Mathematics, starting July of 2002.

Tim Chartier (Mathematics, 2001–2003) works in Numerical Analysis. In 2001, he teamed with Anne Greenbaum of Mathematics and Randy LeVeque of Applied Mathematics to teach and develop materials for our modeling course, Math 381. He and Greenbaum later advised two of the four UW modeling teams in 2002. While at the UW, Chartier developed a collaboration with Loyce Adams of Applied Mathematics leading to two research papers. After two years of VIGRE support, Chartier was appointed to a tenure-track job at Davidson College. He has told us that the department chair at Davidson was very impressed by Chartier’s professional preparation, which Chartier attributes in large part to his VIGRE activities while at the UW.

Jean-Yves Courbouis (Statistics, 2000–2003) was mentored by Paul Sampson and Peter Guttorp. He participated in several working groups sponsored by the National Research Center for Statistics and the Environment (NRCSE), particularly in dynamic graphics, where he worked with several undergraduates, and in sampling, where he participated in a successful center proposal with Oregon State and Colorado State to the EPA. He now works on a project with the National Marine Fisheries Service, jointly with Peter Guttorp.

Oliver Will (Statistics, 2001–2004) is mentored by Elizabeth Thompson and Matthew Stephens. His research is in statistical genetics and genomics, and he is active in the Mathematical Genetics working group.

Bernard Deconinck (Applied Mathematics, 1999–2000) specializes in nonlinear waves. His mentors were Robert O’Maley, Nathan Kutz, and Randy LeVeque. Deconinck was particularly active in mentoring graduate students. For instance, at the request of graduate students and in addition to his regular teaching duties, he ran an informal special topics course on applications of the inverse scattering method to the solution

of soliton equations. Deconinck and Nathan Kutz supervised a number of undergraduate research projects. He was awarded an NSF Math Sciences Postdoc in 2000-2003. In Autumn, 2003, Deconinck will assume a tenure-track assistant professor position in the UW Applied Mathematics Department.

Peter Blossey (Applied Mathematics, 2000–2003), who specializes in fluid dynamics, was mentored by Peter Schmitz. Blossey has collaborated with Peter Schmid and William Criminale. He organized several workshops for graduate students (see below) and has given several talks in the undergraduate ACMS seminar. Since finishing his VIGRE postdoc, Blossey has been working as a postdoc with Randy LeVeque during the summer and recently accepted a Research Scientist position in the Atmospheric Sciences Department at UW.

Brian Walton (Applied Mathematics, 2002–2004) works on problems in mathematical biophysics and applied probability. Walton, his mentor Hong Qian, and graduate student Rafael Meza are studying diffusion approximations to birth-death processes. In addition to ongoing collaborations stemming from his graduate studies, Walton has actively pursued new interdisciplinary connections including active participation in the Mathematics Department’s probability seminar and the interdepartmental Mathematical Biology seminar hosted by the Biology department.

5. PROFESSIONAL DEVELOPMENT AND INDUSTRIAL TRAINING WORKSHOPS FOR GRADUATE STUDENTS

To provide a forum for discussing important topics related to the professions of mathematics and statistics, VIGRE has supported two recent forums, open to all graduate students. The forums were organized by Chartier and Blossey, both VIGRE postdocs. The topic for the first was “Finding an academic job.” A panel of recently appointed faculty from each of our three departments together with the Mathematics Chair at Seattle University told of their experiences and gave advice. Approximately 55 graduate students participated. The second forum, attended by about 40 students, focused on jobs in industry and national laboratories and how to find one. The panel, included a representative from Microsoft, two from Boeing, and one from Livermore National Laboratory (brought to the UW campus with VIGRE support).

We also collaborated with PIMS to host the Fifth Annual PIMS Industrial Problem Solving Workshop.

6. MATHEMATICAL COMMUNICATION

Using VIGRE support as well as matching UW help, taught several courses in mathematical communication. These courses have helped us develop and refine our ideas of what is effective, and how to reach the largest numbers of students. Some of the materials we developed have already been integrated into a basic course in Mathematical Reasoning. Other materials will be integrated into writing modules for our mainstream courses. In the mathematical modeling courses at the core of the ACMS program, VIGRE helped us develop project-based modules with a heavy emphasis on presentation of results.

7. IMPACTS ON OUR GRADUATE PROGRAMS

In addition to the workshops mentioned above, VIGRE helped us improve and broaden our graduate programs.

The quality of applicants has increased. In Mathematics applicants, around 175 annually, are divided into groups using a point system. In 2002 the top group contained 39 people, and all but three of entering PhD students came from this group. In 2003 the entire entering PhD class came from this group, which numbered 44. In Statistics, the number and quality of applicants has gone up, going from 78 to 112 from 2000 to 2003, and using VIGRE funds Statistics has been more successful in landing more of its first-round choices (7 out of 10 in 2003), making them competitive with the best departments in the country. These quality improvements continued to 2004.

VIGRE funds have enabled our graduate students to participate in conferences and workshops vital to their future careers. Over 80 trips by graduate students were funded by VIGRE, often with matched contributions from grants and other sources. Some of these trips were to major international meetings. A dozen graduate students have been placed in internships using our VIGRE framework. VIGRE funding has also facilitated funding students in Statistics with research interests in statistical theory.

As a result of their participation in our third-year review, the VIGRE graduate fellows asked to set up working committees to help plan VIGRE activities. We responded by establishing four cross-departmental committees (with both VIGRE graduate fellows and VIGRE postdocs) that are concerned with undergraduate involvement, web page content, orientation, and general planning. These not only provide useful services, but also help graduate students get to know fellow students in other departments and show them how the different cultures operate.

Graduate students and undergraduates have been supported by VIGRE to participate in such outreach activities as the NSF-funded projects *Creating and Extending the Community of Mathematics Learners* whose co-PIs include Warfield (Math) and Morita (Stat), and the UW GK-12 project, with Adams (AMath) as PI and Warfield as a co-PI.

8. SEATTLE VIGRE WORKSHOP

On April 12, 2003, we held a Workshop for VIGRE sites on the West Coast and in the Southwest. All nine sites sent at least one representative, and Richard Millman from NSF also participated. The goal of the workshop was to exchange ideas and information, share ideas that have worked (and some that have not worked as well as anticipated), and develop new ideas to increase participation in the mathematical sciences, especially at the critical transitions. A report on this discussion, prepared by William McCallum from Arizona, was distributed to participants and to the NSF, and is available at <http://www.math.washington.edu/~lind/VIGRE.html>.