

SUMMIT MEETING: SUMMARY

In 2015, over the course of a weekend, the Department of Mathematics at Northwestern University organized a conference for women undergraduates in the mathematical sciences. In planning this event, we had in mind a single goal: the encouragement of women studying mathematics in the USA to continue their mathematical education at the graduate level.

Our motivation for organizing this conference emanated from two sources. Our department has experienced increasing difficulty in attracting women to apply for its graduate program (and less directly relevant, but still on our minds, an even worse deficit in applications by women for our postdoctoral assistant fellowships and and tenure-track positions). At the same time, fewer women are pursuing majors in mathematics at some of our leading universities.

In applying for an NSF grant to support a second edition of our undergraduate conference, the Division of Mathematical Sciences (DMS) suggested that we request funding for a summit meeting of educators with experience in working on this issue, in an effort to develop ways to evaluate the effects of differing approaches. This request was funded, and we accordingly held a summit on October 13 and 14, 2016, just before the weekend of our GROW conference attended by 80 women undergraduates.

The local participants were Laura DeMarco, Paul Goerss (Chair of the Department of Mathematics), Ezra Getzler, and Bryna Kra (who serves as the PI of the grant). Participants from other institutions were:

- a) Matthew Ando (Chair, Department of Mathematics, UIUC)
- b) Douglas Arnold (Department of Mathematics, University of Minnesota; Former President of SIAM; Former Director of IMA)
- c) Hélène Barcelo (Deputy Director, MSRI)
- d) Dennis Davenport (Department of Mathematics, Howard University; Chair, Diversity Committee of PCMI)
- e) Moon Duchin (Tufts University)
- f) Ruth Haas (Smith College; Director, Center for Women in Mathematics)
- g) Deanna Haunsperger (Carleton College; President elect of MAA)
- h) Dusa McDuff (Barnard College; Organizer of Women and Mathematics, IAS)
- i) Jennifer Slimowitz Pearl (Program Director, DMS, NSF; DMS Infrastructure Program)
- j) Lillian Pierce (Duke University; Program Committee, Women and Math, IAS)
- k) Jill Pipher (Department of Mathematics, Brown University; Past President of AWM; Director of ICERM)
- l) Candice Price (University of San Diego)
- m) Ami Radunskaya (Pomona College; President elect of AWM)
- n) Brooke Shipley (Chair, Department of Mathematics, UIC)
- o) Francis Su (Department of Mathematics, Harvey-Mudd University; President of MAA)
- p) Michael Vogelius (Division Director, DMS, NSF)
- q) Judy Walker (Chair, Department of Mathematics, University of Nebraska; Founder of Nebraska Undergraduate Conference for Women Undergraduates in Mathematics)
- r) Trisha Wonch Hill (Department of Sociology, University of Nebraska-Lincoln)

The viewpoint of the NSF. Vogelius and Pearl, from the NSF, described the roles that NSF plays in the effort to support participation of women in the mathematical sciences: collecting and publishing data on the topic, supporting research to understand what factors impact women's participation, and funding projects that have as a focus supporting women or broadening participation more

generally. Despite years of investment by NSF and others, the percentage of women entering and the percentage of women completing Ph.D. programs has remain relatively constant since 2004, at around 30%. At the same time, the social science and education literature has grown and there is better understanding of effective practices. Vogelius and Pearl asked how can we as a community take what we have learned and attempt to integrate it more broadly to have an impact at the national level? NSF is interested in supporting projects that are scalable to serve large numbers of students without large increases in cost, and sustainable, that is, have continued impact without on-going large influxes of grant funding. Projects that contain a core component of mathematical sciences research as a part of student training can be submitted to DMS, and projects that address educational research questions can be submitted to the Directorate of Education and Human Resources. After the summit, but prior to the publication of this report, NSF published a Dear Colleague Letter NSF 17-078 that encourages such proposals.

Transition from high-school to college and the math major. Pipher reported on Brown's project to change the gateway course for the mathematics major from a calculus course to a topics course. This generated a lot of interest and it was agreed that sample syllabi would be very useful for disseminating this idea.

Su discussed the refurbishment of Harvey Mudd's computer science program to change the level of female participation: this went from 10% to 50% over 10 years. It starts with changes to recruiting: every female admit receives a call from the President. More female faculty taught the introductory courses, which were divided into three streams: black (prior experience), gold (no prior experience), and advanced (two semesters in one). Even including projects with greater social relevance in homework, and painting murals in the CS labs, has helped. And up to 50 undergraduates attend the Grace Hopper Celebration every year.

IAS/Park City Mathematics Institute runs a one-week workshop for faculty interested in mentorship and organizing REUs and other activities specifically for minority students in mathematics.

In discussion, it was decided that it would be useful to evaluate different mentoring programs: peer mentoring or faculty mentoring; formalized versus casual; mathematics alone or mathematical sciences more broadly. We should be learning from other sciences, such as biology: the AAAS web-site STEM Central is an important resource.

There was also discussion of the importance of creating good-quality exit surveys for all aspects of the freshman experience. A repository for sample surveys could be created by the MAA. Hill told us about her research developing tools to evaluate programs and to understand why some approaches work. This involves research on social networks, implicit bias, and STEM identity formation, among others. She would like to collaborate with social scientists to understand better why some programs work.

Transition to graduate school. While around 45% of math majors are women, the fraction in graduate study is lower, around 30%. Kra underlined that it is this drop-off which most concerns us here, and is the underlying reason for the organization of this conference.

Several programs that help women make the transition from undergraduate to graduate study in mathematics were compared.

Haunsperger summarized the experience of Carleton Summer Mathematics Program, a 4 week program for around 18 undergraduate women at the pre-REU level. This incorporates contacts with faculty, graduate students, and the SMPosium, a 3-day conference with PhDs who attended SMP. This program definitely sees an increase in undergraduates advancing to graduate study. It

has been supported for 18 years by the NSF, and has served 329 undergraduates, of whom 90 have completed a PhD in the mathematical sciences and 63 are currently in graduate school.

Haas discussed Smith College's Center for Women in Mathematics post-baccalaureate program for women who want to enroll in graduate programs in mathematics but need some additional preparation. There are 50 applicants for ten slots, half directly from undergraduate programs and half from out in the world. In its 9 years of operation, 90% of participants have entered graduate programs.

Radunskaya spoke of the EDGE (Enhancing Diversity in Graduate Education) program, founded in 1998, rotating among 10 universities since then, that has served 240 participants, of whom one third have gained PhDs at this time (with more in the pipeline). It starts with a 4 week summer program for women entering graduate study in mathematics, and continues from there with mentoring, symposia, and regional clusters.

Ando spoke on the changes in the graduate program at UIUC. These have depended on a hard-working Director of Graduate Studies. In a decade, the fraction of doctorates awarded to women has gone from 25% to 40%, and to URM from 2% to 10%. Some tools used: removal of GRE as factor in application; abolition of comprehensive exams, and replacement by satisfactory completion of corresponding courses; a green/yellow/red alert system for current standing within program; and a focus on recruitment.

It seems that what is most important in this direction is a clearing house where different approaches can be evaluated and compared. Currently, nothing of this sort exists in our profession.

There is also a lot of information emerging from the field of social psychology. Better dissemination of this to faculty around the country would also be valuable.

The profession. We heard from several institutes that have worked to increase the participation of women in their activities. Their experiences have been quite different: this is definitely a subject for further study.

Barcelo discussed the approach at MSRI: to increase the fraction of women in its programs and summer schools requires persistence, vigilance, dedication, and funds. Here is a table of the number of women members of organizing committees of programs (out of 6 or 7) vs. percentage of women among participants:

organizers	0	1	2	3
participants	16%	20%	22%	24%

Pipher told us that ICERM, through active management, has attained a level of 25% female speakers at its meetings. (Lists of speakers with few or no women are knocked back.) The organizing committees are urged to step beyond their personal networks, and it is emphasized that increased diversity increases scientific impact.

Shiple discussed UIC's experience with Women in Science and Engineering System Transformation (2006–11), which was supported by \$3 million from an NSF Institutional Transformation Award. This project was faculty-centered, emphasizing female leadership (3 of 5 STEM departments at UIC have female chairs, all of whom went through this program), improved mentorship of tenure-track women faculty, and life-friendly employment policies. This program saw a 50% increase in the female fraction of STEM undergraduates over its life.

As ever, there is a tension between the limited number of tenured women available to fulfil visible roles in the community and the importance of that visibility to increasing the numbers of women in the discipline. At GROW, for example, we have not hesitated to have a substantial

number of males participating in the presentations and research lectures, both to alleviate this pressure on women and because this presents a more realistic impression of the texture of life in graduate school.

Some women like attending all women conferences, others maybe less. Is it possible to evaluate the effects of holding events like these, and also other events that are overwhelmingly but not entirely attended by women, or 50/50? This also speaks to other issues of diversity in the mathematical community, such as gender diversity.

WORKING GROUPS

The summit broke up into four working groups, which examined the following (partially overlapping) questions, and also presented possible proposals to further some of the ideas identified in the discussions. The four groups were

- (1) Transition from high school to college
- (2) Transition from college to graduate study
- (3) Recrafting American undergraduate mathematics major, with a focus on improving gender ratio
- (4) Underrepresented groups in math: comparisons and contrasts, disparities among institutions

FIRST WORKING GROUP: MENTORSHIP

This group discussed the creation of mentorship networks for budding mathematics students, and more broadly (since it is often all the same for students beginning their college education), students interested in mathematical sciences. These might involve faculty, and also peer mentorship networks. It would be worthwhile to study the effect of such mentorship networks, on both the mentee and the mentor.

We propose the creation of a repository of open source material on best practices in mentoring in the mathematical sciences, as well as on implicit biases, stereotypes, and value affirmation for faculty and peer mentors. The AAAS has already done work in this direction (STEM Central), and it is important to build on that, and not to attempt to duplicate it. Also, it is important to study how extant programs in the life sciences might transfer to the mathematical sciences.

SECOND WORKING GROUP : DIRECTOR OF GRADUATE STUDIES MENTORING WORKSHOP

This group proposed conducting a workshop for Directors of Graduate Studies. It would be useful to bring together faculty with experience at programs that have had some success, such as Illinois, Iowa State and Nebraska. It would also be useful to learn more about other model programs, such as Minnesota+, Rutgers and UIC.

It would be useful to find out more about the outcomes of the “Finding and keeping graduate students in the mathematical sciences” workshops at AIM (held in 2006, 2009 and 2012).

Collaboration with the Posse Foundation might be possible.

The group proposed the following research question: Have the interventions reported on at the Summit led to a improvements in the retention rate for women (and other underrepresented groups) in PhD programs, and also in their success in these programs?

In addition, it might be helpful to perform climate surveys within departments before and after interventions, to develop an understand of the effects beyond the immediate participants. Sample questions for such a survey might include

- (1) Do you feel like you belong to the community?
- (2) Do you have someone you can talk to if you have a problem?
- (3) Competitiveness?
- (4) Measure gender bias (do you think men or women are better at math?)
- (5) Mental health: loneliness and isolation.

The budget for such a workshop might cover the attendance of three workshop leaders. Institutions would pay for their faculty, especially Directors of Graduate Studies, to attend. Some money would need to be budgeted for follow-up, research and reporting.

THIRD WORKING GROUP: RECRAFTING THE UNDERGRADUATE MAJOR

The undergraduate major is in transition and different schools have different success in producing mathematics majors. Data seems to indicate that many strong research departments produce few female majors. Some schools, even large programs, do not have the classes or opportunities for math majors to be prepared for graduate school, and it is not clear how to address this. There are numerous barriers to entry: preparedness for classes, atmosphere in the department, isolation, and methods of evaluation.

One suggestion is that a lot could be achieved by changing the culture, and such programs should not require significant funding. An idea that was extensively discussed is that of ambassadors going out to departments, and an example was given of such a program in the biology community: a goal was to make biology more quantitative, ambassadors attended a workshop, and then returned to home departments armed with techniques to do so.

Adapting this to mathematics, there was significant discussion of the cultural issues particular to mathematics and how to effect change. Social scientists have concrete practices, encouraging a critical mass of faculty to think of success differently.

Particular ideas discussed include:

- (1) Changing the exam structure, finding other ways to evaluate the first year.
- (2) Understanding the pathways as to how students think of the transitions from high school to undergraduate to graduate school.
- (3) Strengthening core subjects such as algebra and analysis for students by running a kickoff week, perhaps before starting graduate school.

FOURTH WORKING GROUP: DIRECTED READING PROGRAMS

The idea is to write a proposal to the NSF EHR for the creation of a Directed Reading Program Network. Directed Reading Programs pair graduate student mentors with undergraduate mentees to collaborate on mathematics book reading projects. The proposal is to expand the existing grass-roots network: this has the potential to recruit more students into mathematical careers and to broaden the pool from which such students are drawn.

DRP was initiated at University of Chicago in 2003 and has spread, mostly at the initiative of alumni of the program, to a number of other universities. The program now exists in some form at: Brandeis, Indiana University, MIT, Rutgers, Tufts, University of Texas Austin, University of California Berkeley, University of Connecticut, University of Maryland, and Yale.

Preparatory data gathering. We will gather data from these individual programs about how they have run their DRP and with what measurable outcomes. For this we will write a short survey and try to reach as many DRP alums as we can. Some of the questions which may be asked:

What level are the projects aimed for? Term-time or summer? Course credit? Pay?
How much direction for the presentations at the end? Any written component? Are the books subsidized? How is topical variety maintained?

What are the demographics of the DRP participants (mentors and mentees) compared to the ambient populations: sex, race/ethnicity, citizenship, year in school? Are there data about persistence in math (both becoming math majors and continuing to grad school)?

We will make comparisons to related models, for example, the Columbia/Barnard capstone seminar (which involves 12 undergraduates and a graduate student mentor) and Harvard tutorials (6 undergraduates and grad student).

Website. We will create a website for the DRP Network including

- (1) A database of pairings
- (2) A list of projects/books with descriptions and reviews (multiple per book possible), possibly including video reviews
- (3) A "Toolbox" to facilitate the set up a DRP at your school, including information on organization, publicity, seeking additional funding, etc.
- (4) A FAQ
- (5) Tie-ins to other programs, such as books which would serve to prepare a student for a particular REU
- (6) Online forms for application, data collection and assessment

Components of proposal and outline of budget. This would be a 3-year proposal, approximately \$290K total.

The first event would be a workshop at MSRI to recruit faculty and graduate students to lead the implementation at their school (duration 1.5–2 days). We might hope to invite 60 pairs consisting of a graduate director and graduate student from graduate programs, and 10 representatives of undergraduate institutions who wish to work with a host doctoral department. [130 participants, \$50K]

We would provide seed money for DRPs on a matching basis. Schools would submit short proposals (one page) stating how they intend to implement a DRP, highlighting (a) sustainability, (b) broadened participation, and (c) persistence in the mathematical career. The Network will match local funding up to \$5K per year. The money could be used to buy books for participants or summer stipends, etc. We will provide a template to facilitate the proposal. [\$50K/yr = \$150K]

A follow-up activity to give a venue for student presentations, and for programs to talk about local successes and challenges.

Assessment involving a social scientist on a consultant/senior personnel basis. [\$10K/yr = \$30K]

Website support. We may try to seek a grad student who takes a substantial coordination role. Over time, we may find this is more suitable as a staff position. [\$20K/yr = \$60K]

Once we have contacted the schools with DRPs and learned who the key personnel have been, we will assemble a team of PIs for the grant. We would like to have a steering committee of 5 people who rotate the lead role for five years.