The Mills College Summer Mathematics Institute & The Berkeley Summer Institute for the Mathematical Sciences

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Introduction

From 1991 to 1997, 155 undergraduate women participated in the Mills College Summer Mathematics Institute (SMI) and the Berkeley Summer Institute for Mathematical Sciences (SIMS). By many accounts these programs were highly successful: to date, 20 of the participants have received PhDs, 24 have received Masters degrees, and 49 are attending graduate school in the mathematical sciences. However, many of the benefits that these women received from the program can not be measured by these numbers alone.

We found that SMI and SIMS provided a valuable short-term intervention for its participants at a crucial stage in their development. The program brought together a critical mass of talented women math majors. These women found it exciting to study mathematics with other women. They encouraged each other, they saw that women can and should study advanced mathematics, and they felt part of a growing network of professional women mathematicians. The program provided them with valuable role models and mentors, practical knowledge of what to expect in graduate school, and it provided them with an experience they could carry with them, an experience that helped prepare them mathematically, pragmatically, and emotionally for graduate school.

History

The Mills SMI was conceived in 1990 during a student strike at Mills College. The Trustees of the college had launched an unsuccessful attempt to make the college coeducational. Student opposition to the proposed change kindled discussions on the benefits of being educated at a women's college, and from one such discussion Steven Givant, Mills College, and Leon Henkin, U.C. Berkeley, hatched the idea for the SMI. The Mills SMI was modeled on a program for minority students that Henkin and Uri Treisman, U.T. Austin, had started at Berkeley the preceding summer. Givant and Henkin worked with Lenore Blum, International Computer Science Institute, and Diane McIntyre, Mills College, to develop the Mills SMI, which began in the summer of 1991.

Although, the program originated at Mills, it was held on both the Berkeley and Mills campuses. In the first year of the program, the Mills dorm, where the participants were housed, was closed for renovations in the fourth week of the six week summer session. Out of necessity, the program moved to the Berkeley campus for its final two weeks. There it was discovered that the students thrived on the research environment at Berkeley with its numerous summer visitors, excellent library and computing facilities, and vibrant graduate student life. The next year, the program was split again with four weeks on the Mills Campus and two on the Berkeley campus. After an overly quiet summer program held entirely on the Mills campus in 1993, the program moved permanently to Berkeley in 1994. At Berkeley, the students were housed in the international graduate student dorm, and SIMS activities took place in the Statistics Department and the Mathematics Department, which are both in Evans Hall.

The first year of the program was funded by the National Science Foundation (NSF). After that, we received funding for three years from the NSF. However, the funding for running the 1993 and 1994 programs was cut successively by about 20%. At that time, the point of view of the NSF was that they wanted to provide seed money for programs with new ideas. Established programs should seek funding from other sources. In response, we secured two generous donations from Genentech, a biotechnology company in the Bay Area. We also secured supplementary grants from the National Security Agency (NSA). From 1994 through 1997, the program was supported by yearly grants from the NSF and NSA. When the program officially came under the aegis of U.C. Berkeley in 1996, we also received funds from the University to help cover administrative costs.

As a result of the yearly fluctuations in funding, the size of the program varied from year to year. It was largest in 1992 and 1994 with 25 students, and it was smallest in 1993 with 18 students.

The directing body of the program also changed over the years, as instructors were invited to join in directing the program. Svetlana Katok taught in the first year of the program, and then directed the program with Givant in 1992. Deborah Nolan became a director after teaching in 1992. Ani Adhikari taught in the 1993 program, and later joined the directors. Helene Barcelo taught in the 1991 and 1994 programs, and helped direct the program in its final year in 1997. Henkin and Givant left the directorship in 1995, 1996, respectively.

The directors of the SMI also organized a conference in 1994 for mathematicians who were interested in starting their own summer math programs for women. The conference was held concurrently with the SMI, and was funded by the NSF. Through the conference, we identified and helped initiate the Summer Mathematics Program at Carleton and St. Olaf Colleges, and the Summer Program for Women in Mathematics at the George Washington University. Another outgrowth of the conference was the publication of MAA Notes 46, *Women in Mathematics: Scaling the Heights* (Nolan, 1997). This book contains seminar descriptions from SMI/SIMS faculty, other program descriptions from conference participants, and perspectives from mathematicians who have been active in the promotion of women in the field.

Program Description

Seminars The heart of the summer program consisted of four seminars – typically two were in classical areas of pure mathematics and two were in areas of applied mathematics. Each student took two seminars, one pure and one applied. The topics of the seminars were usually in areas of mathematics that are not part of the traditional undergraduate mathematics curriculum.

The character of the work was very different from that which is encountered in typical undergraduate courses. Challenged by their instructors, students immersed themselves in the material of their seminars to discover and prove results, without the aid of textbooks. They were given many hard problems, and were encouraged to work on them in small groups as well as individually. They gained experience in the process of searching for and writing up proofs, and they learned how to obtain and express mathematical ideas verbally and in writing. Students were assigned two projects per seminar. In one project, they worked individually, and in the other they worked in small groups of 3 or 4. The project may have included reading a journal article or doing independent research. Each student presented her findings both orally and in a short paper.

Seminars met two times a week, each time for two hours. There were also two section meetings a week, where students received help from the teaching assistant in mastering ideas presented in the seminar and facilitating group projects.

In addition, faculty met twice individually with each student in their seminar. One meeting took place near the beginning of the program, to learn about the student's background and to help her choose appropriate projects. The other meeting was near the end of the program, to discuss the student's progress and help her plan for the future.

Faculty Each seminar was led by a woman who was an active research mathematician and a talented teacher. Teaching assistance was provided by women who were graduate students in the mathematical sciences. The teaching assistants were drawn mainly from U.C. Berkeley and Stanford University.

The SMI/SIMS faculty were: A. Adhikari, Stanford; H. Andréka, Math. Inst. Hungarian A.S.; D. Wallace, Dartmouth; H. Barcelo, Arizona State, Tempe; A. Bluher, NSA; M.L. Bonet, U. Pennsylvania; L. Butler, Haverford; A. Etheridge, Cambridge U.; E. Flapan, Pomona; S. Katok, Penn. State; C. Kenyon, C.N.R.S. Lyon; N. Mackey, Michigan S.U.; M. Murray, Virginia Polytechnic; D. Nolan, U.C. Berkeley; V. Pless, U. Ill. Chicago; U. Porod, U.C. Berkeley; A. Radunskaya, Pomona; L. Schneps, C.N.R.S. Paris; A. Thompson, U.C. Davis; L. Walling, U. Colorado, Boulder; and S. Wang, Mills.

Of the 21 faculty who have led seminars, 5 returned to lead seminars for a second year; and 3 have directed the program. In addition, 8 have contributed descriptions of their seminars to MAA Notes 46 (Nolan, 1997).

Colloquium. In addition to the seminars, a series of colloquium talks were held twice a week. The talks introduced students to a vast array of advanced mathematical topics. In 1996 the speakers included Ken Ribet on Diophantine problems and Hellegouarch-Frey curves; Galia Dafni on the Fourier transform and analytic number theory; Abby Thompson on knots and 3-manifolds; David Aldous on shuffling, sorting and randomness; David Blackwell on Polya urns; Elinor Velasquez on the dynamics of springs and particles; Valentin Rybenkov on topological equilibrium in DNA; Larry Gonick on cartooning mathematics; Charles Pugh on Brouwer's fixed point theorem; and Dana Randall on random tilings on lattices.

Panels, Information Sessions, and Site Visits. Four evening events were planned each summer. First was an information session on the process of applying to graduate school and finding financial aid. A second evening was set aside for a panel discussion on graduate programs, where mathematicians from several universities spoke about graduate schools, the different programs available, the graduate school experience, and the difficulties and rewards one might encounter in graduate school. A third event was an informal discussion held with the seminar leaders, where they give a brief history of their professional career, including how they decided to go to graduate school, why they chose their field of interest, what it is like to do research, what an academic career is like, and how they balance family and career. Finally, a panel was held where representatives from organizations that conduct mathematical research outside the university discussed different career opportunities in the mathematical sciences. In 1996 and 1997, we organized site visits to some of these organizations. Students visited the Lawrence Berkeley Laboratories, Genentech Corp., and Barra Inc.

Each year, we also organized visits to: the Mathematical Sciences Research Institute at Berkeley, Stanford University, and U.C. Davis.

The Students

Each year, we sought 18 to 24 women who had completed, with top grades, two or three years of undergraduate mathematics courses (including some upper division work involving substantial exposure to proofs). To evaluate applicants, we requested two faculty evaluations, a math course report that included the textbook used in each course, an official transcript, and a personal statement.

We primarily admitted students from small institutions which are unable to offer the diversity and strength of courses needed to make their students competitive for admission to a strong Ph.D. program. Other students were from large regional state universities, places that might not provide enough encouragement to students to continue their studies. Some students admitted to the program were studying at well-known research institutions with strong mathematics programs. We found that students from these institutions also benefited from our program, and that these students often inspired the others to continue their studies in mathematics.

Of the 67 participants in the 1991, 1992, and 1993 programs, 20 have received PhDs and are now working as research mathematicians; 13 are currently in graduate school, in the mathematical sciences; and 10 have received Masters degrees in the mathematical sciences. Of the remaining 24 students, 12 are employed in quantitative fields as consultants, actuaries, high school math teachers, and software developers.

Of the 68 participants in the 1994, 1995, and 1996 programs 37 are currently in graduate school; 15 have obtained Masters degrees in the mathematical sciences; and 6 of the remaining 16 with Bachelors degrees are employed in quantitative fields.

Evaluation of the program[1]

We undertook a comprehensive evaluation of the program in the summer of 1996. The evaluation had three components:

- Surveys of the 1993 and 1994 participants, for information on the influence the program had on them.

- Surveys of the faculty who wrote letters of recommendation for students admitted to the 1994 and 1995 programs, for their perceptions of the effect the program had on the student.

[1]This section is an excerpt from Adhikari, Givant and Nolan (1997) *Women in Mathematics: Scaling the Heights*, MAA Notes 46, pp97-104.

- A brief survey of the graduate advisors of the 1991 and 1992 participants who were in graduate school in 1996 and working on a thesis, to see whether the student is making satisfactory progress towards her degree.

We include a summary of some of the main responses to these surveys here.

Results from the student survey. Altogether, 80% (34 out of 43) of the students responded to the survey. The questions in the surveys for the 1993 students and the 1994 students were similar; however, the 1994 students were asked about the effect of the program on the following year of undergraduate school. Over 60% of these students said that the program had a great deal of effect on their choice of advanced undergraduate courses. (Others pointed out that their schools did not offer many advanced courses.) The students also engaged in mathematical activities outside the classroom: over half gave talks at their home institutions, and over half participated in math clubs or conferences. Students appreciated the wealth of information provided by the program on the process of applying to graduate programs and applying for fellowships.

Questions about the effect of the program on their graduate experience were asked of both 1993 and 1994 students. Students are admitted to the SMI only if they have strong math records. Thus, one might expect them to be strongly predisposed towards graduate school before coming to the program. Nevertheless, the responses to the survey make clear that the program plays an important role in shaping their decisions about graduate school.

About half of the students said the program had a great impact on their motivation to do graduate work, and about half said that it provided them with a sense of what grad school would be like.

> I feel that I was better prepared to handle the demands of graduate school ... The atmosphere of the program opened my eyes as to what would be expected of me.

The strongest influence of the program is on the students' estimation of their own capabilities. Over two-thirds reported that their self-confidence was greatly enhanced by the SMI, and these results were confirmed by the undergraduate and graduate advisors. According to one student,

> Perhaps the program's main advantage for me is that I feel very comfortable being in grad school. That is, I feel that I belong here, as opposed to some of my female peers who have many doubts about their ability and place in this environment.

Over 60% of the students strongly agreed with the statement, "My work in the program showed me I enjoyed doing challenging math." It is worth noting that two of the students who strongly disagreed also said that the program convinced them that graduate school was not their goal; this is a valuable lesson, even though in a sense it is negative. In addition, over half the students strongly agreed with the statement that the program showed them "how to learn advanced math." This percentage is surprisingly high, given that students in the program are selected for their ability to do mathematics, and it underscores the difference between work in the SMI and in standard undergraduate classes.

In end-of-program evaluations, the students have been consistently and overwhelmingly positive about the "all women" nature of the program. It is now clear from the survey that this effect is long-lasting. Over 80% of the students have stayed in touch with fellow students from the program, and over 70% with their professors in the program. Over half the students asked for letters of recommendation from their SMI professors. A student sums up the opinion of the vast majority as follows:

> Until attending the SMI, I had only had one female math professor. Ever. I think I now have a great advantage in having discovered some positive female role models in mathematics. ... I found the program ... to be extremely helpful to seeing myself as a mathematician. I don't recall ever seriously being told that girls don't do math. But on the other hand, until attending SMI, I rarely actually saw them doing it.

Results from the undergraduate faculty survey. The response from the undergraduate faculty who wrote letters of recommendation for the SMI participants was very positive. Three quarters (33) of them responded. Six were unable to judge the effect of the program, because they had no contact with the student after her return.

For the faculty who did have contact with the student after her return, more than 80% said the program was very beneficial. Also, about half said their student's participation in the program had an effect on the whole department. Two themes recurred throughout their comments: they noticed a tremendous increase in the self-confidence and in the mathematical maturity of the student upon her return. One respondent commented,

> Clearly, the major benefit to [her] was realizing that she was the mathematical equal of some of the most talented women of her age. While her background in course work was not as strong as some, her mathematical training and ability let her participate as an equal. This was exceptionally helpful to her and did wonders for her self-confidence.

Concerning a different student, another wrote,

> [She] mathematically matured a great deal as a result of your program. I noticed that the analytical and topological concepts ... meant a lot more to her than they did to other students.

The students with whom the six respondents had no contact were from Princeton, Stanford, Berkeley, and Johns Hopkins. All of these students did stay in close contact with their SMI professors, receiving letters of recommendation and advice about graduate school. Two of them even wrote undergraduate theses under the long-distance supervision of their SMI professors. We interpret this as evidence of the benefit of the SMI to undergraduate women at major research universities: the SMI provides them with invaluable support that is missing at their home institutions.

The faculty respondents also provided information on the record of their institution in sending women to graduate school in mathematics. At roughly one-quarter of the schools, at most one female student goes to a graduate program in mathematics in any five-year period;

at one-quarter, one female student goes every other year; at one-quarter, one goes about every year; and at the remaining quarter, about two go each year. These numbers make it clear that undergraduate women usually have little contact at their home institutions with other women who plan to attend graduate school in mathematics. By way of contrast, at the SMI, students find themselves part of a significant group of women dedicated to math, over two-thirds of whom go on to do graduate work in the mathematical sciences.

Results from the graduate advisor survey. In 1996, sixteen of the 1991-92 students who responded to our survey had begun work on a thesis, and of these, 13 allowed us to contact their thesis advisors. (Fourteen of these 16 have completed their Ph.D.s and the remaining two expect to finish in the next year). The advisors' responses were unanimous: each student is making satisfactory progress toward her degree. Many advisors responded with accolades such as: "one of our best in the past five years," "the most dedicated student that I have ever seen," "a model graduate student," and "a lot of self-motivation." We see a confirmation of these opinions in the quantitative part of the survey. According to the advisors, the students have a great deal of self-confidence and motivation, and they arrived at graduate school knowing what to expect.

When asked "How does the student compare to other women in your program in terms of adjusting to the demands of graduate work?" the advisors had insightful comments, and offered great encouragement. For example, one advisor wrote:

> As an undergraduate, [she] attended a small state college and received an education that really didn't give her the necessary background for graduate school. Nevertheless, she arrived here in graduate school imbued with confidence and the desire to work hard ... She has passed all her qualifying examinations and is now writing a dissertation under my direction. She is a joy to have as a student; she's talented and energetic. If your program had anything to do with this, then you should certainly consider it a success.

What happens to the faculty that teach in the program?

We asked 12 seminar leaders from 1991 to 1995 (excluding faculty who had directed the program) to tell us what effect the program had on them. All responded to our request. They resoundingly confirmed that the SMI is a valuable opportunity for them as well as for the students. Here are excerpts from three statements.

From a 1991 seminar leader:

> [The program] had a big and beneficial influence on me. I gained a unique teaching experience. The experience was beneficial for me from the point of view of my mathematical research also. Collaboration with Steven Givant in the theory of relation algebras turned out to be very fruitful and is marked with several joint papers since then. I had mathematical collaborations with other researchers in the Bay Area (e.g. William Craig, Richard Thompson).
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> I would recommend working in this program to any good mathematician, because I find it very precious and unique, and because it is really enjoyable for creative people.

From a 1993 seminar leader:

> I cared about every single one of the women I had in my seminar at the SMI (they were all potential future women professors in the mathematical sciences), so I was highly motivated to make the seminar a wonderful experience for every student. This is precisely the attitude that ... every liberal arts college professor must cultivate. ...
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> The SMI has created a network of women mathematicians nationwide. This year I have an NSF Visiting Professorships for Women grant. When I think about whom to invite to talk about doing mathematics with women graduate students, ..., I automatically think of professors who have taught in the SMI. My professional ties with several colleagues in my field have been strengthened because we share the experience of teaching in the SMI and related summer programs for women.
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> I think it is a wonderful service opportunity for women mathematicians with established research reputations.

From a 1994 seminar leader:

> I have always tried to get students to participate actively in the classroom. However, while I was teaching in the SMI, I was able to engage students more both in my presentations of new material and through problems that they worked on in groups. After my experience in the program, I developed a clearer idea of how to ask questions in class which would get the students involved in thinking about the material, and telling me how the proofs should be done. Now almost all the proofs which are presented in my classes are constructed by the students. Also, I began putting deeper problems on my homeworks, and making more of an effort to get students to work in groups. As a result I think that the students are learning the material better and becoming more interested in the material in my classes.

References

1. Nolan, D. (1997) *Women in Mathematics: Scaling the Heights*, MAA Notes 46.
2. Adhikari, A., Givant, S., and Nolan, D. (1997) The Mills College Summer Mathematics Institute. In *Women in Mathematics: Scaling the Heights*, MAA Notes 46, pp97–104.