

## Twelve Years of Summer Program for Women in Mathematics – What Works and Why?

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We have been running the Summer Program for Women in Mathematics (SPWM) at George Washington University for twelve years. In this paper we describe the major components of our program and why it works. We have found, and believe, that the women in general, and our program participants in particular, have strong intrinsic abilities to succeed at high levels in sciences and mathematics; what they sometimes lack is self-confidence. We provide a nurturing environment and role models whose examples and encouragement help these women reach their potential.

### 1. Brief History

In 1995 we hosted a 4-week pilot program for 10 undergraduate women mathematics majors from around the United States. The program was initiated, in part, to replicate the success of the Mills College Summer Mathematics Institute (SMI) that had at that time been running for almost a decade. A multi-institution proposal was made to the National Science Foundation (NSF) to create similar programs at a number of institutions in the country but that proposal was declined. We were subsequently asked by the National Security Agency (NSA) if we could run a smaller program as a pilot. Through the support of our university administration, we were able to set up a program, invite student applications, find faculty and visitors, and operate a program that, by every measure, was a terrific success. Each of the participants was glowing in support of the program and every one of the directors, instructors, and teaching assistants felt that the program provided a tremendous benefit to each participant. In 1996 and 1997 we hosted a similar 4-week program for 16 undergraduate women. In 1998, the program was expanded to 5 weeks and is continuing in this format for its thirteenth year in 2007 with the continuing support of the National Security Agency.

### 2. Program Goals

The stated goals of our program are to communicate an enthusiasm for mathematics, to develop research skills, to cultivate mathematical self-confidence and

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independence, and to promote success in graduate school. We bring our participants into contact with successful women mathematicians in academia, industry, and government. We provide the students with a broad exposure to mathematical culture, illustrating the beauty and attraction of mathematics, the tools necessary for success in mathematics, applications of mathematics to business and industry, and the career opportunities available to mathematicians. The specific objectives of our program are to provide an immersion program representative of key aspects of graduate school and professional mathematical practice, promote active mathematical thinking, underscore the beauty and enjoyment of mathematics, foster a camaraderie among the participants that emphasizes collaboration and peer support, bring the participants into contact with active mathematical researchers through guest lectures and field trips, provide interaction with a wide variety of successful women in mathematical sciences who serve as role models, illustrate the role of mathematics as the foundation of the sciences and the wide range of mathematical applications in government, business, and industry through first-hand contact with applied mathematicians, and provide students with information about graduate schools and careers in mathematics.

### 3. Program Statistics

We have, by now, hosted 186 students in the past 12 years (1995-2006). A summary status of the accomplishments of our SPWM Participants from 1995 to 2004 is contained in the following Table. Information on 2005 participants is incomplete and the 2006 participants are still undergraduates.

TABLE 1. Education Data on SPWM Alumnae.

Finished PhD	Finished MS	Working on PhD	Working on MS
21 Participants	26 Participants	52 Participants	8 Participants

Note that there is some overlap between the people who went to MS programs and then continued to PhD programs. Some of our participants are untraceable partly because they may have got married and changed last names. (We use many techniques to track our participants, especially from earlier years. This includes contacting their college professors, the alumni offices, as well as search engines.) The following Table contains data on the employment status of our participants, as known to us.

TABLE 2. Employment Data on SPWM Alumnae.

Professor/ Post-Doc	Industry/Government	HS Teaching	Vet/Law/Others
16 Participants	30 Participants	13 Participants	11 Participants

### 4. Program Elements: Courses and Teaching Faculty

The main purpose of our summer program is to introduce the participants to graduate level topics not covered in typical undergraduate curricula. The current format consists of two 3 week courses and two 2 week courses. These (noncredit)

courses are taught by women mathematicians who design the special courses for our program and use a variety of teaching techniques including individual and group study. The students generally start these courses from scratch – without a prior exposure to the course topics. At the end of these courses, the participants know enough about the topic that they are able to make in-class presentations; some of the presentations are very slick. Each year, we produce proceedings of the summer program containing copies of the student presentations and the students take copies of these proceedings as cherished mementoes of their summer program experience.

We bring teaching faculty from all over the country and sometimes from overseas. In 2006, our teaching faculty consisted of Barbara Csima, Univ. of Waterloo, *Computability Theory*; Lyn Miller, Slippery Rock Univ., *Introduction to Groebner Bases*; Angela Gallegos (SPWM 1998), Occidental College, *Mathematical Modeling in Biology*; and Karma Dajani, Univ. of Utrecht, *An Introduction to Discrete Financial Mathematics: The Binomial Model*. We also invite two graduate students to serve as teaching assistants each year; in 2006, our teaching assistants were Sara Miller, University of Notre Dame and Tiff Troutman, University of California-Riverside; both are former SPWM participants from 2002.

Here is a sampling of our courses from previous years; complete details are posted on the summer program website: <http://www.gwu.edu/~spwm>.

Lynne Butler, Haverford College, *Number Theory and Public Key Cryptography*, 2005

Ayse Sahin, DePaul Univ., *An Introduction to dynamical systems*, 2005

Sylvie Hamel, McGill Univ., *Introduction to Automata and Language Theory*, 2003

Janet Talvacchia, Swarthmore College, *Introduction to Symplectic Geometry*, 2003

Joanna Kania-Bartoszynska, Boise State Univ., *Introduction to Knot Theory*, 2002

Leila Schneps, Ecole Normale Supérieure, *Fermat's Last Theorem*, 2001.

## 5. Program Elements: Guest Lectures

The guest lecturer program is an important feature of our summer program. We invite a wide variety of mathematician professionals (mostly women) who come to GWU and spend an afternoon and evening with our participants. The guest lecturers give a specially prepared talk, provide information on their own decisions that took them into the field of mathematics, and entertain discussion on their background, education, and career paths. Listed below are the guest lecturers and the titles of their talks for 2006.

Professor Cathy O'Neil, Barnard College, *Local to global principles*; Professor Linda Smolka, Bucknell University, *Shocks, Waves, Fans and the Method of Characteristics*; Dr. Tad White, National Security Agency, *Algorithmics and Statistics of String Comparison*; Professor Jane Hawkins, University of North Carolina, Chapel Hill, *An introduction to cellular automata*; Professor Allison Pacelli, Williams College, *Algebraic Number Theory: an "Ideal" Subject*; Professor Rebecca Weber, Dartmouth College, *Making randomness rigorous*; and Professor Annalisa Crannell, Franklin & Marshall College, *Math and Art: The Good, the Bad, and the Pretty*.

## 6. Program Elements: Field Trips and Panel discussions

We have a field trip each week where our participants come into contact with women mathematicians in their own workplace, and are exposed to current issues at the forefront of mathematics, the variety of applications of mathematics, the depth and complexity of the kinds of mathematics involved, and the possibilities for careers related to mathematics. In 2006, the field trips were to U.S. Census Bureau; Dibner Library, Smithsonian Institution; Science Committee Room, U.S. House of Representatives; National Security Agency and National Cryptologic Museum; Northrop Grumman- TASC; and The Aerospace Corporation. Each year we also hold two or three panel discussions, each with several invited guest experts from industry, academia and government. At these panels we consider issues associated with the mathematics community such as careers, the job market, gender issues and graduate schools.

## 7. Our participants

We bring students from a variety of large universities and smaller liberal arts colleges. We have received applications from large private and public universities including many of the Ivy League institutions, as well as from small four year colleges which may have only 3-4 faculty members in the mathematics department. All of our participants are math majors (some are double majors) and everyone has a strong motivation and interest in graduate school, strong letters of recommendations, and an average GPA from 3.2 to 4.0. Many of the participants have previously attended a Research Experiences for the Undergraduates (REU) program; some have also attended the Budapest semester. Our participants have told us that their reasons to attend SPWM are to:

- *Prepare for the world of graduate school,*
- *Opportunity to explore math,*
- *Increase my knowledge of math,*
- *To meet future colleagues and build lasting academic relationships,*
- *To be exposed to new ideas I may not experience in the regular classroom,*
- *To experience mathematical study outside classroom setting,*
- *Give me the confidence needed to pursue my inherent passion for mathematics,*
- *Curious to see what mathematicians outside of academia do.*

Because of the advance nature of topics covered in our courses, we find it is helpful if our participants have taken courses in abstract/modern algebra and real analysis or advanced calculus. We receive 100+ applications each year; in some years we have received as many as 160 applications from highly qualified and motivated students. We work hard to select the summer program participants, based upon their academic background and their Statement of Interest. We essentially look for a passion for mathematics and their desire to learn and go forward as mathematics professionals. Letters from their professors are often very helpful – in many cases, the professors tell us about their students' achievements and passion for mathematics that the students might be too modest to tell us.

### 8. Follow-ups: Networking

We attempt to contact our participants at least once a year. We continually update our database to keep track of the participants and have recently started compiling a SPWM Newsletter which is regularly updated and made available to our program participants. The program faculty, teaching assistants, guest lecturers and our hosts at field trip sites provide a valuable resource to the program participants. This includes writing letters of reference for graduate applications, pointers for job applications, help with graduate school search and application process, help with job interviews, and actual jobs. We held a program reunion in January 2000 at the Joint Mathematics Meetings (JMM) which was held in Washington, DC that year. Since 2000, we have sought, and received, extra funding from the program sponsors to invite former participants each year to attend the Joint Mathematics Meetings and have had six annual summer program reunions at JMM. We support a limited number of participants to travel to the meeting site and have found that the most recent participants, who are still undergraduates, get the most benefit from these reunions. However, many of the old timers are happy to get together to share ideas and provide support to one another.

### 9. Program Evaluation

We carry out program evaluations at mid-point and the end of each program. We also approach our program participants for their impressions about the effectiveness and long term value of our program; many of our participants are happy to give us their positive feedback years after their attendance at the summer program. Here is a sampling of what the students have told us at the program end:

- *I wanted some direction to my future, as well as a better ability to articulate what I love about math and what mathematicians do. This program addressed my main concerns and much, much more. It was amazing.*
- *This has been an excellent experience. I now feel confident about graduate school. I also feel confident about my choice to be in mathematics... I now know I can succeed in math.*
- *It was great reading the research papers. It was very encouraging to realize that I know enough to read other people's work.*
- *I gained a wealth of information and insight. I'm now convinced that I can succeed in grad school.*
- *I think the presentations really helped me gain some confidence in my abilities.*
- *I learned so much math, got a taste of math culture, and grew as a person I think. In fact I grew a lot . . .*
- *I am amazed at how much more aware I am now than I was a month ago.*

Here is what an NSF program manager told us after spending a day visiting our summer program:

*I think it's important that we continue to encourage women in the mathematical sciences. Far too often I run into the attitude that the women "problem has been solved" and those who don't think this is necessary aren't always men. I like what GWU does with the courses that it gives the participants. This provides the context for the discussions and talks throughout the rest of the program. Having the participants work on projects is also a very positive aspect of the program. They seem to*

*enjoy the interaction and they reinforce each other in a very congenial environment. Having them give presentations of their work is a highlight of the program, in my opinion. Presenting the results of their investigations is something that can only benefit them in their future.*

Here is a sampling of what our participants told us a few years after their participation:

- *As for the summer program. I found it very effective. It definitely convinced me to attend graduate school. It also gave me confidence in my abilities.*
- *My impressions of the program..... I think it was one of the most important things I ever did. I needed to be with other girls who were math majors. There were a lot of things we had in common that I didn't get to share with people at my own university.*
- *I believe that the summer program helped me tremendously. It gave me an idea of what grad school would be like and it helped encourage me to go on with my studies. I still keep in touch with a few others so I have also made some lasting friendships.*
- *.... the program really helped me a lot to develop more mathematical sophistication and to appreciate the ever-growing world of mathematics. It was also really great to understand math in a more global sense: not only were we taking classes from disciplines we'd never heard of before (Measure Theory), but we were taking classes with people from all over the country, and with teachers from all over the world. So, I really think that this universal aspect of mathematics is something that I only appreciated after the program, and especially now in graduate school.*

## 10. What have we learned?

We have learned that the women participants are extremely capable of doing graduate studies in mathematics and obtaining advanced degrees at prestigious institutions. Many of our participants come from smaller institutions where they might not have been exposed to a large variety of mathematics; our program shows them that there is a lot more to mathematics than what they may have experienced in their undergraduate career. Many of the women lack self-confidence and often think that graduate school is out of their reach; even after starting the graduate programs they may think that they alone are having the frustrations usually experienced by many graduate students – both male and female. Our networking opportunities are extremely valuable to the participants – the fact that they come to know so many math professionals outside their own institutions and the fact that they can call upon these people for advice and help is priceless. A nurturing and nourishing environment enables these women to remove their self doubts and find the spark needed to go forward and excel as a mathematician. Their visits to the national conferences to see the prominent mathematicians in person leave a lasting impression on the younger participants. The opportunity to get together once a year to compare notes, renew friendships, and offer advice continues to be extremely valuable to our participants.

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