



## MathILy-EST 2023 Final Report

### Preface

The MathILy-EST Research Experience for Undergraduates (REU) was created to serve college-age students that are early in their college career (i.e., an emphasis on freshmen, but with consideration for sophomores and even graduating high-school seniors). Also, this REU runs in parallel to the 5-week MathILy program for talented high-school students. Both programs take place at Bryn Mawr College, with all the students and staff sharing the same dorm building.

### Program Preparations

#### Promotions

*Emails:* Notes advertising MathILy-EST were sent to multiple email lists in the professional math community, and to (an updated list of) contacts at Historically Black Colleges and Universities, Minority Serving Institutions, the Hispanic Association of Colleges and Universities, Leadership Alliance coordinators, and to contacts at McNair programs and Black and Latinx student centers.

*Fliers:* A MathILy-EST alumn took 50 fliers to the Field of Dreams conference for us. No other MathILy-EST-specific fliers were handed out, though 450 {MathILy, MathILy-Er} fliers that mention MathILy-EST were handed out at HMMT and sent to two high school math contests.

*Webpages and links:* MathILy-EST has its own webpages, and is listed on the NSF-REU pages (of course) as well as the AMS Opportunities pages, the Institute for Broadening Participation's [pathwaystoscience.org](https://pathwaystoscience.org), the Math Alliance website, and the Art of Problem Solving's wiki. There are also several online lists of math REUs that include MathILy-EST.

*Site traffic:* There were about 11,500 impressions for the [mathilyest/index.html](https://mathilyest/index.html) page and 5,300 for the [mathilyest/facts.html](https://mathilyest/facts.html) page over the 2022–2023 season.

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*Other Activities:* sarah-marie held an AoPS Math Jam on REUs in general and MathILy-EST in particular in February. There were about 25 people at most times, a high point of about 40; 270 people entered/left over the hour-and-a-half.

## Applications and Admissions

*Demographics:* There were 90 completed applications for the 9 REU slots. Applicants originated from 27 US states. Of course, some states were over-represented, with at least 12 students from MA schools, 11 from PA, 9 from NY, 9 from CA, 7 from TX, and 4 each from IN and RI.

In terms of the demographics during the stages of making decisions, we have the following percentages:

Stage in application	Female	NB/Trans	Asian-American	Black	Latinx	SLAC
All applicants	30%	10%	23%	3%	6%	26%
Long list (34)	44%	8%	18%	12%	12%	26%
Short list (19)	42%	5%	11%	11%	11%	21%
Accepted	56%	0%	11%	11%	22%	22%

Four of the nine students invited responded within an hour, and the last student responded in just 12 hours (in the middle of the night).

## Personnel

*Administrative:* The MathILy-EST 2023 Director was Dr. Brian Freidin (Assistant Professor at Auburn University). Lily Wang (graduate student, University of Michigan) was the Graduate Research Apprentice menTor at MathILy-EST (GReAT-EST). The PI on the NSF grant was sarah-marie belcastro (President of Mathematical Staircase, Inc.). The {MathILy, MathILy-Er, MathILy-EST} Minion was Madison Stuart.

*Senior Personnel:* These individuals gave advice on the construction of MathILy-EST and the NSF proposals for the grants that fund the program.

Hannah Alpert, mathematics faculty at Auburn University (MathILy-EST director 2020)

Max Engelstein, mathematics faculty at University of Minnesota (MathILy-EST director 2021)

Brian Freidin, mathematics faculty at Auburn University.

Nate Harman, mathematics faculty at University of Georgia (MathILy-EST director 2022)

Thomas Hull, mathematics faculty at Western New England U. (MathILy-EST director 2019)

Emily Peters, mathematics faculty at Loyola University Chicago.

## What Happened at MathILy-EST 2023?

### Academics/Research

The research topic was algebraic geometry over finite fields. The students were split into three groups working on three extensions of a central problem on counting transverse-free varieties.

*Reading:* Leading up to the program the Director gave the students a reading assignment. The Director chose seven research papers for students to read, and assigned one student to each of six papers and three students to the final paper. Each paper contained relevant background information for the summer's research projects. Each student made a Coauthor post summarizing their paper, and gave a presentation to the other students on it during the first week.

*Mathematical Explorations:* All three groups looked at extensions of a 2021 paper of Asgarli and Freidin bounding the proportion of smooth projective curves over finite fields that admit no transverse lines. The first group (PAGA) looked at curves in the affine plane over a finite field, relating curves, singularities, and tangencies to extended curves in the projective plane. The REU group extended projective arguments to work in the affine plane and include singularities.

The second group (Texas) looked at the prevalence of non-smooth transverse-free curves in the projective plane. They studied arrangements of singular points and tangency conditions to prove that, for large finite fields, most transverse-free curves have singularities. In fact they proved that most transverse-free projective curves contain singularities at all the points of a line.

The third group looked at the phenomenon of transverse-freeness in higher dimensions and other geometries. They began by considering surfaces in projective 3-space, comparing the properties of being tangent to every line or to every plane. They proved that in low degree (degree  $q+1$  and  $q+2$  over the finite field with  $q$  elements) these properties never coincide. They then moved on to studying finite analogues of spherical and hyperbolic geometry, constructing low-degree examples of transverse-free curves in these settings.

*Writing (during and after):* At the start of the summer most of the writing was in the form of Coauthor posts. Initially these were formal assignments: the reading and presenting assignment involved making a Coauthor post, and each day during Week 1 there was an official notetaker to make a Coauthor post with notes from that day's Ever-EST seminar.

Once the research groups formed, the Director continued to encourage the use of Coauthor, though was less specific about the format of their posts. Each group continued to post in Coauthor with a mix of descriptions of strategies and directions, pictures and diagrams, and proof attempts.

In the third week each student was assigned to write a mini-paper with one result they had proved in the previous week. Most students wrote these up in Overleaf documents, and then posted a pdf to a Coauthor thread where the GReAT-EST and Director could give feedback on writing style in addition to mathematical content. Several students wrote up more mini-papers in later weeks for individual feedback before beginning work on a full paper writeup for the summer. Around week 6 each group made a shared Overleaf document to combine all their work into a paper draft.

The three groups are writing three separate papers for publication in research journals, although progress has been slow since the Fall semester started.

## Professional Development

*Daily Gathers and Week of Chaos:* The MathILy-EST students were told to attend all of the MathILy Daily Gathers and each was allowed to enroll in one Week of Chaos class. All nine MathILy-EST students decided to take a Week of Chaos class.

*Presentations:* The MathILy-EST students made several presentations as a group. Every time someone visited MathILy to give a Daily Gather, the visitor was asked to spend time with the MathILy-EST students to hear a presentation on their research. The director also arranged for a mathematician in the area to visit and talk with the students.

During the last week of MathILy, the MathILy-EST students gave a Daily Gather. They introduced the main objects they were studying, arrangements of points and lines in finite geometries, led the MathILy students to discover some basic properties about blocking sets and point-line correspondences, and then they stated their main research questions. This took a fair amount of time to plan and rehearse, but the Daily Gather went well and everybody had a fun time.

In the last week of MathILy-EST (and the weeks after) the students prepared their abstracts for the JMM. They hope to give three 20-minute talks in a special session on undergraduate research, all of them joint. Two groups are additionally planning to give a poster presentation. All 9 students are currently planning to attend the JMM.

*Software:* During the first week the Director and GReAT-EST ran an Ever-EST session on LaTeX and BibTeX, as well as one on Sage and Mathematica. Two of the three groups used Sage to explore their problems in different ways, and every student wrote proofs in LaTeX throughout the summer.

*Other professional development:* The MathILy-EST students were guided to write their own professional CVs, and heard attended a panel discussion about graduate school by the MathILy staff. There were also professional development seminars on writing papers, giving presentations, how to use MathSciNet/arXiv to look up journal articles, and one on ethics in research and mathematics. MathILy-EST participants also attended multiple MathILy Life Seminars.

*Social Activities:* MathILy-EST students had a lot of fun this summer. Activities included: chamber music (with MathILy students), Hanabi, EvenQuads, knitting, and exploration around campus.

### **Administrative matters**

*Facilities and staff at Bryn Mawr:* The physical environment that Bryn Mawr provided for the MathILy-EST students was excellent. Three modern “fish bowl” style conference rooms in the recently renovated section of the Park Sciences Building were provided for exclusive use by the REU students. These rooms each had floor-to-ceiling blackboards and a wide-screen TV for projecting computers, and one also had a whiteboard.

### **Post-Processing**

*Post-program senior personnel meeting:* After the end of the program, there was a meeting to discuss the program and to plan for next year. Tom Hull will direct the REU in 2024.

*Impact:* Students rated all aspects of their MathILy-EST experience as very or somewhat valuable (except for one “not useful” rating in each category and two “not useful” ratings of Daily Gathers), and eight of nine participants stated that participation in MathILy-EST has positively influenced their career path or career. Every student visited a MathILy class, and almost all found it an interesting experience. Almost all MathILy-EST participants reported socializing with MathILy students outside of their classes, and all found it fun, interesting, and valuable. Over 90% of the MathILy students found MathILy-EST somewhat or very valuable to their MathILy experience in general, with 75–90% giving these ratings on each specific aspect queried.

#### *Finances summary:*

The income from grant NSF DMS-1851842 was \$8,043.

The income from grant NSF DMS-2149647 was \$99,095.

Total MathILy-EST income: \$107,138.

Administrative expenses were \$86.

Total stipends (director, participants) were \$52,342.

Total wages (MathILy director and Minion) were \$3008.

Total non-wage employee expenses were \$258.

Program expenses (t-shirts, pens, stickers) were approximately \$475.

Travel expenses for participants were \$12,679.

Site expenses from Bryn Mawr were \$40,586.75.

Total MathILy-EST expenses: \$109,177.

The above totals do not reflect \$1955 in wages and expenses not yet reimbursed by the NSF (future income); the remaining \$84 overage comes entirely from expenses that are not covered by NSF funding. Note that the above includes travel expenses from the Joint Mathematics Meetings for the 2022 MathILy-EST cohort.