



MathILy 2016 Final Report

Preface

MathILy was about 40% larger in its fourth year as in its third year. As usual, we held a program with excellent students who learned a lot of mathematics and a lot about how to think and speak and write mathematically.

Program Preparations

Promotions

Electronic: Emails were sent to promising applicants from 2015 and to MathILy 2015 participants. MathILy continues to be listed on several high-traffic webpages, including the AMS summer programs page, the MIT Admissions' "Prepare for MIT" summer programs page, and the Art of Problem Solving Wiki summer programs page.

Print: The full-color quarter-sheet fliers were redesigned to show {MathILy, MathILy-Er} logos interlocked. About 2000 fliers with basic information on one side and a multi-part mathematics problem on the reverse were distributed at national and local mathematics contests and enrichment activities. Fliers were handed out at HMMT and ARML.

Other Activities: At HMMT, sarah-marie gave a Mini-Event (on Minkowski sums) and was available to talk with students, parents, and coaches at various times. She also offered a Math Jam (on foury, fourier, fouriest numbers) through the Art of Problem Solving that was followed by a {MathILy, MathILy-Er} Q&A, and gave the Friday Night Lecture (on floorquence sums) at ARML Penn State, before and after which she met with potential applicants, admitted students, and alumni/ae.

Applications

Statistics: We received 462 Short Forms, 139 Not-as-Short Forms, and 140 EARs. There were 120 completed applications, of which 49 became admitted students. The admissions rate is about 41%, which is as we expect. Four students declined for other national-level summer mathematics programs.

Demographics: Not-as-Short Forms originated from at least 26 US states and 12 foreign countries (representing mostly North America, Europe, and Asia).

The data in the following table was measured where possible and approximated otherwise.

Percentage	Female	East Asian	South Asian	Latin@	Other of color
Short Forms	34%	37%	19%	3%	2%
EARs	28%	41%	11%	1%	3%
Attending	19%	33%	17%	0%	2%

Financial Aid: Donations earmarked for financial aid totaled \$1000, and we were awarded an AMS Epsilon Fund grant for \$5000 (required to be used for financial aid). We were able to award \$21,400 in financial aid to MathILy participants because of the budgetary stability provided by the Epsilon Fund grant and because of lower-than-budgeted costs (particularly in instruction). All but two admitted students' demonstrated need was met, and both students were still able to attend.

Personnel

Academic: Lead Instructors were Dr. Hannah Alpert (ICERM and Ohio State U., Ph.D. MIT 2016), dr. sarah-marie belcastro (Smith College Research Associate, Ph.D. University of Michigan 1997), and Dr. Thomas C. Hull (Western New England U., Ph.D. University of Rhode Island 1997).

Apprentice Instructors were Brian Freidin (grad student, Brown), Emil Guliyev (software engineer, Apple), Hallie Voulgaris (undergraduate student, MIT), Corrine Yap (grad student, Rutgers University), and Evangelie Zachos (grad student, Stanford University).

Biographical information and prior experience are listed at <http://mathily.org/dramper.html>.

Administrative: The Director was dr. sarah-marie belcastro. The excellent {MathILy, MathILy-Er} Minion was Madison Stuart (Smith College B.A. 2006 in Mathematics and German; graduate work in information science at the University of Michigan). The Protector and Responder in the MathILy Environment (PRiME) was Rob Quarles (Berry College grad 2016 in Mathematics and Chemistry).

Advisory Amalgam: These individuals gave advice on academic and practical aspects of MathILy.

[Dr. Douglas J. Shaw](#), mathematics faculty at University of Northern Iowa

[Dr. Ruth Haas](#), mathematics faculty at Smith College

[Mr. James Cocoros](#), mathematics faculty at Stuyvesant High School

[Dr. Dylan Shepardson](#), mathematics faculty at Mount Holyoke College

[Dr. Carol E. Fan](#), operations researcher (currently at the Gap)

[Dan Zaharopol](#), Executive Director of [BEAM](#)

[Dr. James Tanton](#), mathematician, currently Ambassador for the [MAA](#)

[Dr. Joshua Greene](#), mathematics faculty at Boston College

[Dr. Emily Peters](#), mathematics faculty at Loyola University Chicago

[Wing L. Mui](#), mathematics faculty at the Overlake School

[Dr. Thomas Hull](#), mathematics faculty at Western New England University

[Dr. Josh Laison](#), mathematics faculty at Willamette University

Student Demographics:

States represented by MathILy students, roughly from east to west: Maine, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Florida, Ohio, Michigan, Tennessee, Indiana, Illinois, Wisconsin, Missouri, Minnesota, Texas, California, and Washington.

Countries outside of the United States represented by MathILy students, roughly from east to west: China, India, Greece, Serbia, Poland, and Canada.

Gender breakdown: 7 females, 29 males.

Ages: There were three 14-year olds, eight 15-year olds (one turned 16 during the program), twelve 16-year olds, nine 17-year olds (one turned 18 during the program), and two 18-year olds.

Academic backgrounds: Two-thirds of the students had already taken calculus II or equivalent (and 1/9 had also taken multivariable calculus), and one had taken college linear algebra. Fourteen students had attended mathematics programs in previous summers.

What Happened at MathILy 2016?

Academics

Classes: Each weekday we had 4 hours of morning class, 1–1.5 hours of Daily Gather, and 3 hours of evening class, for at least 8 contact hours per day (not counting mathematical conversations outside of class). Weekends were a bit idiosyncratic, but the general Saturday template consisted of 4 hours of morning class and 1–2 hours of afternoon Life Seminar.

The basic curricular structure was two weeks of core curriculum, called Root Class (after the root of a graph theoretic tree, and after the idea that the material strengthens student grounding much as the roots of a tree do), followed by one week of short topical classes, called Week of Chaos, followed by two weeks of focused-topic classes, called Branch Class (after branches of mathematics, and after the idea that tree branches grow from a strong trunk nourished by roots).

Root Class: There were three Root classes, each with 12 students, one taught by {sarah-marie, Corrine, half-Brian}, one taught by {Tom, Hallie, half-Brian}, and one taught by {Hannah, Emil}. The material included from our core curriculum was linear and affine algebra and geometry (including equations and intersections of hyperplanes, span, linear independence, and dimension), combinatorics, graph theory, definition and examples of groups, isomorphism and homomorphism for various categories, probability spaces and expected value, and basic cardinality. Of course, all of this material was treated with full proofs given by the students. Three students worked on our new advanced linear algebra curriculum.

Week of Chaos: Students indicated which of 42 potential topics they would be excited to learn about, from which instructors decided on a list of classes offered. These were Projective Geometry, Moar algebra: Basic Algebraic Geometry, Anagrams (complex analysis), Banana-related Shenanigans (Lebesgue integration), Purely Theoretical Computers (deterministic finite-state automata), Erdős Magic (the probabilistic method), Primey Numbers (p-adics), Let's Generate Some Functions!, Parallel and Non-parallel Universes (non-Euclidean geometry), Information Theory, Knot Theory–Practice, The Donuts Hate You (classification of topological surfaces), Algorithms for Alpacas, Math Saves the World: Combinatorial Optimization, Surreal Numbers: A Love Story, Finite Geometry, Moar Algebra—not the linear kind (group theory), Ramses Theory (Ramsey theory), Origametry, and Spectral Theory. Each student was placed in 5 classes according to expressed preferences. Almost half of the classes used specific material from the Root curriculum, and a few benefitted substantially from students' knowledge/understanding of linear algebra.

Branch Classes: We offered three Branch classes, one was on computational and discrete geometry, taught by Tom and Corrine, one on the mathematics of computation (both discrete and continuous), taught by Hannah, Brian, and Hallie, and one on convex geometry and polytopes taught by sarah-marie and Evangelie. All three Branch classes introduced real-world applications.

Pedagogy: All classes were conducted using inquiry-based learning, with the bulk of the time spent with students working in groups or presenting their insights to each other and a much smaller amount of time used by faculty conducting discussion from the board.

Feedback: Students received feedback in multiple ways. They received instant verbal feedback on the correctness of their mathematical ideas during class, as well as feedback on use of notation, language, and presentation style. They received written feedback on the problem solutions and proofs they

handed in each day, always within 24 hours of handing in work. Near the end of Root and Branch classes, each student was asked to write an introspective self-evaluation. The self-evaluations were discussed by the student's instructors, and the instructors then held a 5–20 minute meeting with each student to give overall feedback on the student's progress at MathILy and advice for the future.

Daily Gathers: Each instructor gave a Daily Gather. The Daily Gather timeslot was also used to show Math Movies once per week. These included expository films made by the Mathematical Association for America's Geometry Project, films from the National Film Board of Canada, and narrated animations made by individual mathematicians or research groups. One such Daily Gather included a round of Orthogonal Questions. The remainder of the Daily Gathers were given by visiting mathematicians, both local (Lafayette, Swarthmore, and Lebanon Valley Colleges, and Lehigh University) and from Georgia, Massachusetts, Texas, and Washington DC.

Extracurriculars

Life Seminars: There were three weekend Life Seminars offered. The first was on practical matters such as how to address faculty in person or by email and how to do laundry. The second Life Seminar was on careers for people with mathematical science training, with a section on the college application process. The third Life Seminar was on how to choose colleges to which to apply, and included an exchange of information about instructor experiences at several colleges and universities.

Other all-program activities: At the end of the first week, we walked over to Haverford College, had a mini Daily Gather in their math lounge, and returned to Bryn Mawr. We then gathered in our largest classroom to play a rousing game of telephone pictionary. The program went by train to Philadelphia for the entire Saturday right after Week of Chaos. The next day, the program was treated to ice-cream cones and dishes at a local shop on National Ice Cream Day.

Non-program-wide activities: A group of students regularly used the indoor athletic facilities. Because the weather was often oppressive this summer, students were more likely to play frisbee after dark than in the afternoon, though they regularly tossed discs around between dinner and evening class.

The program could barely fit in one large common area, so students generally broke into groups to socialize. Card games were very popular this year; there were often three different groups playing at once (always Dominion, often standard-deck games, and often SET or Apples to Apples or lesser-known games). Unsurprisingly, Pokémon GO was popular, and made more so because Bryn Mawr had many Poképportunities.

Most nights there were optional Bedtime Stories; attendance was about a third of the students. We were given a key to a music practice room this summer, and it (and the room) was in constant use. A small group of students regularly sang along to the sound track of *Hamilton*. Other students spontaneously did modular origami together. On the last night of the program, we brought lots of puzzles to the common area and many of the students played with them late into the night and again on departure day.

Administrative matters

Facilities at Bryn Mawr: Again, everyone liked the facilities and the campus as a whole. We were in the same part of the same dormitory as last year. Some students had air-conditioned single rooms, and others shared two-room doubles or three-room triples. We were assigned our choice of classrooms in the math-and-physics floor of the science building. Janitorial service was extensive; every night chalkboards were cleaned and the rooms were tidied.

Campus Location: Bryn Mawr is a safe and tree-filled suburb of Philadelphia, located on a major train line into the city. Bryn Mawr College is a few blocks away from the Bryn Mawr train station, and also a few blocks away from a major street that parallels the train line and has lots of shops, libraries, post offices, etc. This location was convenient for our purposes—many desired destinations were a short walk away or required a straightforward and quick drive. Students were able to depart campus on foot in groups to go out for dinner or shopping. It was also straightforward to take the program into the city, and use of the train made our travel flexible.

Post-Processing

Post-program staff meeting: After (most of) the students had left, the staff convened to evaluate various aspects of the program and to discuss how we could improve the workings of MathILy in future.

We continue to be happy with the Root core curriculum, and the LIs collectively added detail to the linear algebra parts of the curriculum. Our use of additional problem sets given selectively to alumnus and advanced students worked well. We agreed that undergraduate AIs should be given feedback on their marking of student written work. The new AIs thought that it was helpful for us to have a discussion of how to plan for Week of Chaos classes in the week before they happened. We used new ways of collecting and analyzing student preferences this year; while this made scheduling more straightforward and less stressful, the process took just as long as before. Finally, we discussed the academic impacts of having international students compose a third of the program.

Collectively, we felt that the students were slightly stronger this year than in previous years, and were therefore surprised that as a group they did not grow more mathematically. Still, we were fundamentally satisfied with student progress.

Impact: As usual, several students commented

- on how much they learned while at MathILy
- that they are even more excited about math now
- that they learned about areas of math of which they hadn't even dreamed
- that they are now certain they want to pursue more mathematics.

Finances summary:

The income from student fees (some discounted) was \$142,437.

Donations earmarked for financial aid were \$1000.

Our Epsilon Grant award was \$5000.

Total MathILy income: \$148,437.

Administrative expenses (insurance, fliers, etc.) totaled approximately \$2349.

Total wages (instructors, PRiME, Minion, Director) were approximately \$41,245.

Travel costs (Daily Gather speakers, instructors) were approximately \$3731.

Program expenses (supplies, program outings) were approximately \$2905.

Site (Bryn Mawr College) charges, including housing, meals, and duplications were \$87,243.

Total MathILy expenses: approximately \$137,473.

It is notable that we budgeted \$9334 in wages for instructors who came with their own support, and this accounts for about 40% of the financial aid we were able to award.

We were also fortunate to receive in-kind donations of volunteer time and travel expenses related to {MathILy, MathILy-Er} (though mostly MathILy), worth roughly \$11,589, about \$65 worth of bedsheets, and software from Wolfram Research, valued at \$5080.