



MathILy 2022 Final Report

Preface

In addition to a return to in-person operations, MathILy had more participants than ever before. As usual (not just in honor of our 10th program), 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: Individual emails were sent to prior participants and promising applicants. MathILy continues to be listed on several high-traffic webpages, including MIT Admissions’ “Preparing for MIT” summer programs page. Web traffic varied from 5000–17000 hits/month, with about 40% of the traffic from abroad.

Print: None, as most contests were either cancelled or happened virtually.

Other Activities: We held a {MathILy, MathILy-Er, MathILy-EST} Yearly Gather at the Joint Mathematics Meetings (online, April), where about 20 participants team-solved a Jonah-Ostroff-designed Google Sheets flower-themed puzzle about polyomino placement. At HMMT February online, sarah-marie gave a Mini-Event on Minkowski sums over Zoom. In April she offered an Art of Problem Solving Math Jam (about 55 participants) on decorative borders followed by a {MathILy, MathILy-Er} Q&A. While ARML was held in person, we were not present this year.

Applications and Admissions

Statistics: We received 1311 Short Forms, 492 Not-as-Short Forms, 451 EARs, and 388 completed applications. We admitted 65 students; thus, our current admissions rate is roughly 17%. Twenty-one students declined, eight for three other summer mathematics programs and one to help with refugees from the invasion of Ukraine. We routinely ask attending students about their first choice of summer program. This year 21 of the 44 attending students said MathILy was their first choice.

Demographics: Applicants originated from at least 39 US states/territories/districts and 43 foreign countries (representing mostly North America, Europe and Asia, but also including the Middle East, Africa, and South America). The data in the following table was measured where possible and approximated otherwise; the final row reflects a post-program demographic survey given as part of assessment for the MathILy-EST NSF grant.

Percentage	Female	NB	East Asian	South Asian	Latinx	Middle Eastern	Black, Indigenous
Short Forms	34%	>1%	37%	26%	4%	8%	2%
EARs	37%	1%	49%	19%	3%	2%	1%
Attending	27%	0%	52%	15%	2%	0%	0%

Financial Aid: We awarded \$19,925 in financial aid to MathILy participants (\$13,300 to international students and \$6,625 to domestic students), and used our \$6000 AMS Epsilon Fund grant for this purpose. Only 9% of admitted students applied for financial aid; we met the demonstrated need of all applicants.

Personnel

Academic: Lead Instructors were Dr. Hannah Alpert (Auburn U., Ph.D. MIT 2016), dr. sarah-marie belcastro (Math Staircase Inc., Ph.D. U. of Michigan 1997), Dr. Brian Freidin (Auburn U., Ph.D. Brown U. 2018), Dr. Nate Harman (U. of Michigan, Ph.D. MIT 2017), Dr. Thomas C. Hull (Western New England U., Ph.D. Univ. of Rhode Island 1997), and Dr. Daniel Studenmund (Binghamton U., Ph.D. U. of Chicago 2014). Apprentice Instructors were Alvin Chiu (graduate student at UC-Irvine, MathILy 2017), David Gonzalez (graduate student at UC-Berkeley, MathILy 2014), Nadav Kohen (graduate student at Indiana U., MathILy 2015), Joshua Mundinger (graduate student at U. of Chicago, MathILy 2013), Kye Shi (graduate student at UCLA, MathILy 2015/2016), and Natasha Ter-Saakov (graduate student at Rutgers U., MathILy 2014/2015). Biographical information and prior experience are listed at [Dramatis Personae](#).

Administrative: The Director was dr. sarah-marie belcastro. The excellent {MathILy, MathILy-Er} Minion was Madison Stuart (Smith College B.A. 2006 in math and German; graduate work in information science at the University of Michigan). The PRiME FACToRs (Protectors and Responders in the MathILy Environment and Facilitators of Activities and CriTiquers of wRiting) were Katie Forbes (undergraduate student at Princeton U., MathILy 2018) and Jonathan Shoung (undergraduate student at Carnegie Mellon U., MathILy 2018). The PRiME FACToRs had academic roles as well.

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 University of Hawaii

[James Cocoros](#), mathematics faculty at Hunter High School

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

[Dr. Carol E. Fan](#), operations researcher (currently Operations Data Science Lead at Apple)

[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](#), Seattle-area artist and former mathematics teacher

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

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

Student Demographics

U.S. States represented by MathILy students, roughly from east to west: Massachusetts, New York, New Jersey, Pennsylvania, Virginia, North Carolina, Indiana, Illinois, Texas, Washington, Oregon, and California.

Countries outside of the U.S., roughly from east to west: Brazil, Canada, India, the Netherlands, Poland.

Gender breakdown: There were 12 female and 32 male participants.

Ages: There were two 14-year olds, thirteen 15-year olds, eighteen 16-year olds, and eleven 17-year olds.

Academic backgrounds: Half of the students had already taken calculus II or equivalent (and 13% had also taken multivariable calculus), and three had taken linear algebra. In contrast, 9% of the students had not yet taken precalculus. Twenty-six students had attended summer mathematics programs before.

What Happened at MathILy 2022?

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, as always, a bit idiosyncratic, but the general Saturday template consisted of 4 hours of morning class and 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 14 or 15 students, one taught by {sarah-marie, Natasha, JoSho}, one taught by {Hannah, David, Alvin}, and one taught by {Daniel, Nadav, Katie}. Our core curriculum consisted of linear and affine algebra and geometry (including equations and intersections of hyperplanes, span, linear independence, transformations, and dimension), combinatorics, graph theory, definition and examples of groups, isomorphism 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.

Week of Chaos: Students indicated which of 63 potential topics they would be excited to learn about, from which instructors decided on a list of 28 classes offered. These were: Algebraic Geometry, A Cubic Formula, Strange Geometries, How the PRiME FACToRs took over MathILy (voting theory), Math Saves the World: An Introduction to Infectious Disease Modeling, Moar Combinatorics, Secrets and How to Keep Them, Rook Research, The Geometry of Mordor (projective geometry), Proving Through Random Show and Tell (zero-knowledge proofs), Game Theory, Math about Math (mathematical logic), Knitting Mathematics and the Mathematics of Knitting, Blackboard Geometry (finite geometries), Terraforming Planets (graph coloring), Fractal Fun Haus, Numbers from Scratch (surreal numbers), Build Your Own Vending Machine (finite-state automata), A Helium Atom's Quest for Home (random walks), *spop* (p -adics), Ramsey theory, Math Saves the World: Combinatorial Optimization, Because the Internet: Information Theory, Fibonacci Identities, Don't Solve for x : Generating Functions, Fancy Note-Taking Diagrams (sorting algorithms), Knots and Links, and A Complicated Exploration (complex analysis). Student preferences guided placement of each student into 5 classes. More than half of these classes used specific material from the Root curriculum, approximately $1/4$ benefitted substantially from students' knowledge/understanding of linear algebra, and about $1/5$ used technology heavily.

Branch Classes: We offered three Branch classes, one on convex geometry and polytopes (sarah-marie and David, themed around an expedition to the polar North), one on chip-firing games (Brian and Nadav with Katie, themed around literal timesharing), and one on the mathematics of paperfolding (Tom and Natasha and Kye, themed around conspiracy theories). All three Branch classes used linear algebra, all three used computer algebra systems, and all three of them 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. Students were assigned to take comprehensive notes for future class reference, and after instructor review (and revision) were copied and distributed to the class.

Feedback: Students received feedback in multiple ways. During class, they received instant verbal feedback on the correctness of their mathematical ideas, and also on use of notation, language, and presentation style. Likewise, students received daily written feedback on their mathematical writing. 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.

Interactions with MathILy-EST: MathILy-EST participants intermixed with MathILy students for group work in Daily Gathers throughout the program. Additionally, each MathILy-EST participant took a Week of Chaos class. Some MathILy-EST participants occasionally took breaks to visit MathILy evening classes.

Daily Gathers: Each instructor gave a Daily Gather, as did the MathILy-EST research group. 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, films from the National Film Board of Canada, and narrated animations made by individual mathematicians or research groups. The remainder of the Daily Gathers were given by visiting mathematicians. Each Daily Gather speaker provided some insight into that person's perspective on the mathematical enterprise and/or way of being a mathematician.

Extracurriculars

Life Seminars: There were five weekend Life Seminars offered, many with time for open questions. The first was on practical matters such as how to address faculty in person or by email, and impostor syndrome. The second Life Seminar was on careers for people with mathematical science training. The third Life Seminar was about preparing for Branch, when to start research, and issues surrounding collection of demographic information. The penultimate Life Seminar was on how to choose colleges to which to apply, and included advice from MathILy-EST participants. The final Life Seminar, held the following afternoon, was on how to readjust to the non-MathILy world post-MathILy.

10th MathILy alumni panels: In honor of the 10th MathILy, we held three Zoom panels of alumni, on the topics of summer experiences in college, alumni careers, and attending graduate school outside of math. Almost every panelist independently attested to finding the linear algebra they learned at MathILy to be incredibly useful later. There were plenty of questions from current MathILy students.

Official social activities: At the end of the first week, we walked over to tour Haverford College, then returned to Bryn Mawr for a rousing game of telephone pictiography. We celebrated National Ice Cream Day by treating the program to ice cream at a local shop.

Unofficial social activities: There was regular use of the outdoor ping-pong tables, occasional games of frisbee, and a couple of iterations of capture-the-flag. Groups of students played collaborative board and card games, played D&D, worked on jigsaw puzzles, and created/performed song parodies. Most nights there were Murderbot-related Bedtime Stories. This was sometimes preceded by the improvised parodic *Killbot Diaries*. A MathILy-EST participant brought an excess of stickers and shared; these ended up on class notes. Googly eyes appeared in many places in the dormitory, seemingly at random and anonymously. During a heat wave, the PRiME FACToRs supplied water balloons and set up the dormitory slip-n-slide. There was much discussion of the dorm vending machine's video showing $\int |x| dx$. Several students held in-person post-program meetups and shared photos in Slack.

Administrative matters

Pandemic precautions: We required rapid testing on arrival for all participants, masking everywhere for the first week, and then allowed unmasking in MathILy-only spaces on evidence of a second negative rapid test. Masking was mandatory indoors in shared spaces. We ate all meals outdoors. No visitors were allowed inside the dormitory and students were not allowed to leave campus during MathILy.

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 nearby shops that supply toiletries and foodstuffs. Actual grocery stores are a short drive away.

Facilities at Bryn Mawr: Again, everyone liked the facilities and the campus as a whole. We were assigned our own dormitory with air-conditioned rooms and some air-conditioned lounges. In addition to our usual two small classrooms in Park Science Center, we were assigned a large renovated classroom with wraparound floor-to-ceiling blackboards. Janitorial service is extensive at Bryn Mawr; every (early) morning chalkboards were cleaned and the rooms were tidied.

Post-Processing

Post-program meetings: After the official end of the program, the staff convened to evaluate various aspects of the program and to discuss how we could improve the workings of MathILy in future. We plan to create some additional staff documentation, add structured expectations for MathILy-EST/MathILy interactions, and add some evaluation examples to our teaching training.

Impact: As usual, many students commented that they learned about completely new areas of math, and that they are even more passionate about mathematics, and that their mathematical communication skills improved significantly. Additionally, several students said that they now appreciated applications of mathematics of which they were previously unaware, that their mathematical confidence increased, and that inquiry-based learning was a revelation in terms of depth of understanding.

Finances summary:

The income from student fees (some discounted) was \$195,220.

Grant support (Epsilon, individual researchers) was \$32,192 [or \$30,243, see below].

Total MathILy income: \$227,412 [or \$225,463, see below].

Administrative expenses (insurance, fliers, wage-related costs) totaled approximately \$6215.

Total wages (instructors, PRiME, Minion, Director) were approximately \$70,436.

Travel costs (visitors, instructors, students on financial aid) were \$9549.

Program expenses (supplies) were approximately \$3910.

Site expenses from Bryn Mawr were \$137,649.

One-year MAA membership for interested students is \$375.

Total MathILy expenses: approximately \$222,196.

The individual researcher NSF grants supported subsistence and stipends for trainee staff members, subsistence and travel for students on financial aid, and the time of one instructor (in-kind, so not listed above, worth \$4328). As of this writing, we are awaiting a determination of whether a particular flight qualifies for reimbursement from a researcher grant. We were also fortunate to receive donations of software from Wolfram Research worth \$8456, and volunteer time worth roughly \$780.

The net revenue of approximately \$5216 [or \$3267] arose primarily from having fewer staff members for Week of Chaos than intended.