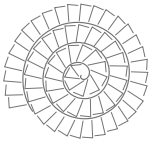

Mathematical Staircase, Inc.

MathILy

MathILy 2024 Final Report

Preface

Despite the many challenges beyond our control (see *Pandemic precautions and outbreak,* and *Facilities at Bryn Mawr*), 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 5,900–17,300 hits/month, with about one-third of the traffic from abroad. The second-most popular page (after the MathILy home page) is Discrete Mathematics in the Real World, accounting for about 28% of website visits.

Print: sarah-marie handed out about 50 fliers at the Harvard-MIT Math Tournament (HMMT), and the Minion sent about 800 fliers to other contests.

Other Activities: We held a {MathILy, MathILy-Er, MathILy-EST} Yearly Gather at the Joint Mathematics Meetings, where at least 110 participants team-solved a Jonah-designed seven-part puzzle with a meta-puzzle that used the solutions to the prior seven parts. At HMMT February sarah-marie gave an Education Event on Tetris-y Tilings, with 65–70 attendees split across two adjacent rooms (she ran back and forth). In late March she offered an Art of Problem Solving Math Jam (about 60 participants) on Foury, Fourier, Fouriest Numbers that included a {MathILy, MathILy-Er} Q&A.

Applications and Admissions

Statistics: We received 2052 Short Forms, 833 Not-as-Short Forms, 746 EARs, and 675 completed applications, each about 20% more than 2023. We admitted 60 students, for an admissions rate of ~9%. Sixteen students declined, twelve for other summer programs. Thus, our current yield rate is roughly 73%.

Demographics: Applicants originated from at least 40 US states/territories/districts and 46 foreign countries (representing North/South America, Western/Eastern Europe, East/Central/Southeast Asia, North/West/East Africa, and the Middle East). The data in the following table was measured where possible and approximated otherwise; the final row reflects a post-program demographic survey.

Percentage	Female	NB	East Asian	South Asian	Latinx	Middle Eastern	Black and Indigenous
Short Forms	28%	3%	47%	21%	4%	6%	2%
EARs	29%	2%	58%	14%	3%	2%	1%
Attending	24%	5%	46%	10%	7%	0%	5%

Financial Aid: We awarded $20,400 in financial aid to MathILy participants ($10,600 to international students and $9,800 to domestic students), and used grants from Jane Street ($10,400) and the AMS Epsilon Fund ($10,000) for this purpose. Of admitted students, 18% applied for financial aid; we met the demonstrated need of all applicants.

Personnel

Academic: Lead Instructors were 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. Georgia, PhD MIT 2017), Dr. Berit Givens (Cal Poly Pomona, PhD U. Wisconsin-Madison 2003), and Dr. Katie Haymaker (Villanova U., PhD U. Nebraska-Lincoln 2014). Apprentice Instructors were David Gonzalez (graduate student at UC-Berkeley, MathILy 2014), Aurora Hiveley (graduate student at Rutgers U.), Frank Lu (graduate student at Harvard U., MathILy 2018), and Ian Shors (graduate student at UCLA, MathILy 2018). 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 were Adrian Thananopavarn (just graduated Princeton U., MathILy 2017/2019), Emily Shambaugh (entering graduate student at U. Nebraska-Lincoln), and Mackenzie Basinger (just graduated Allegheny C.). 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, (retired) 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 Mathematician at Large with the MAA
Dr. Joshua Greene, mathematics faculty at Boston College
Dr. Emily Peters, mathematics faculty at Loyola University Chicago
Wing L. Mui, Seattle-area comic store owner, artist, and former mathematics teacher
Dr. Thomas Hull, mathematics faculty at Franklin&Marshall College
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, Georgia, Michigan, Louisiana, Illinois, Texas, Kansas, Nevada, Washington, Oregon, and California.
Countries outside of the U.S., roughly from east to west: Brazil, Canada, China, and the UK.
Gender breakdown: There were 11 female, 2 nonbinary, and 31 male participants.
Ages: There were fifteen 15-year olds, sixteen 16-year olds, ten 17-year olds, and three 18-year olds.
Academic backgrounds: Two-thirds of the students had taken calculus II (and 18% had also taken multivariable calculus) and five had taken linear algebra. Unusually, all students had taken precalculus. Twenty-five students had attended summer mathematics programs before.

What Happened at MathILy 2024?

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 15 or 16 students, one taught by {sarah-marie, Ian, Adrian}, one taught by {Nate, Aurora, Mack}, and one taught by {Brian, Frank, Emily}. 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, examples of groups, isomorphism for various categories, probability spaces and expected value, and basic cardinality. Of course, students gave full proofs for all of this material.

Week of Chaos: Students indicated which of 53 potential topics they would be excited to learn about, from which instructors decided on a list of 26 classes offered. These were: To p and Beyond! (p-adics), Even Cooler New Numbers (complex analysis), Origametry, Euclid Schmeuclid, Playing with lasers: Projective Geometry, Why we can't have nice things (voting theory), Game Theory, Linear Counting (linear algebraic methods in combinatorics), Polynomial Counting (combinatorial nullstellensatz), Don't Solve For x: Generating Functions, Secrets and How to Keep Them (cryptography), Math Saves the World: Combinatorial Optimization, Slicing Bread Differently (Lebesgue integration), Mixing potions with the magic of prime divisors: Number theoretic functions and Mobius inversion, The Little Sky (finite fields), Home Before Dark (random walks), Loops on loops on loops (homotopy theory), For free squares, scan this code (quadratic reciprocity), From CDs to the Cloud: Error-Correcting Codes, Small pictures (finite geometries), Which Shape is Best Shape? (isoperimetric problems), Agents of Chaos, Knot theory, practice, Compress, cmprss, cmprs: Information Theory, Fibonacci identities, and Big finite diff (finite difference calculus). Student preferences guided placement of each student into 5 classes. Nearly 2/3 of these classes used specific material from the Root curriculum, nearly 1/3 benefitted substantially from students' knowledge/understanding of linear algebra, and nearly 1/4 used technology in a significant way.

Branch Classes: The Branch classes were on on convex geometry and polytopes (sarah-marie and Frank and Ian, themed around wild botany) and on chip-firing games on graphs (Brian and David and Aurora, themed around physics and magic). Both Branch classes used linear algebra, both used computer algebra systems, and both 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 were completely integrated with MathILy students and staff, both mathematically and socially. They collaborated with MathILy students at Daily Gathers throughout the program. Additionally, each MathILy-EST participant took a Week of Chaos class.

Daily Gathers: Each instructor gave a Daily Gather, as did the MathILy-EST researchers. We had seven external visitors. Each Daily Gather speaker (both visitors and staff) provided some insight into that person's perspective on the mathematical enterprise and/or way of being a mathematician. The Daily Gather timeslot was also used to show Math Movies once per week including expository films and animations.

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 and included both Zoom and in-person visitors. 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.

All-program activities: At the end of Week of Chaos we we walked over to tour Haverford College and the next day celebrated National Ice Cream Day by treating the program to ice cream at a local shop.

Social activities: Even before the start of the program, students were at it on Slack, arguing that Madison (the Minion) is a robot and providing photoshopped "evidence." Campus "bookstore parties" spawned the regular consumption of sour gummi worms at "Trolli time," undrinkable instant boba parties, mega bubble tubes used to blow bubbles around everyone on the way to class or dinner, and gender/age-inappropriate purchases of "Bryn Mawr Grandma," "Bryn Mawr Grandpa," and "Bryn Mawr Mom" shirts.

Card games The Crew and Корова 006 (Cow 006) and the video game Celeste (because of a 90% off sale) were often in play in the dorm common spaces, which also hosted groups playing Mario Kart, watching sports, and a lot of karaoke. Most nights Bedtime Stories read from *Skunk and Badger*, *Lizard Music,* and *Nettle and Bone*. Two students arranged a Plank Countdown math contest, in which students/staff planked while answering math contest problems; a different pair of students arranged an #overheard stats team-played game show.

A student who was training in power lifting gave people new nicknames (most often "dawg") and fistbumped everyone in greeting many times each day. Another student gave Frank a new fancy braided hairstyle on many days. One day at dinner this student got up and loudly said that she and a different student were getting divorced (we hadn't known they were married). Not long after, the second student got up and asked if they could talk and the first student announced that she'd moved on. This became an ongoing (mild, fake) drama both at dinner and on Slack. At most meals, there were wasps at our tables, clearly attracted most to cooked chicken. There were debates over whether it was more effective to provide decoy chicken or to simply eat one's chicken very quickly so the wasps would lose interest. On the final night of the program, some of the alumns revealed a short puzzle hunt they had created for the cohort.

Administrative matters

Pandemic precautions and outbreak: We did 5 days of daily rapid testing on arrival for all participants and masked when indoors around non-MathILy people. We ate most meals outdoors, but when it rained we brought meals back to the dorm to eat. Students were not allowed to leave campus during MathILy except when accompanied by staff. During Week of Chaos, an instructor fell ill with COVID-19 and the following day a student fell ill with COVID-19. The commonality between the infected individuals was daily masked contact with a student who had left campus overnight without notice a few days before. During the outbreak all students and staff masked, and 5 days later tested all negative for COVID-19.

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 (which hosts a farmers market on weekends), and also nearby shops that supply toiletries and foodstuffs.

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, but because our preferred dorms were under renovation, this summer our dorm had mostly triples and had small bedrooms and showers. Two of our three classrooms in Park Science Center had floor-to-ceiling blackboards. Janitorial service is extensive at Bryn Mawr; every (early) morning chalkboards were cleaned and the rooms were tidied. The dining hall staff went out of their way to be helpful to us, and made a variety of extra dishes exclusive to our program.

Post-Processing

Post-program meetings: As usual, the staff convened after the students left (first in person, then over Zoom) to evaluate various aspects of the program and to discuss how we could improve the workings of MathILy in future. We identified about 15 tweaks to implement, most involving revisions of documents.

Impact: As usual, students commented that they learned about completely new areas of math and did so in depth, that they are even more passionate about mathematics, and that their mathematical communication skills improved significantly. Additionally, several students were excited by seeing connections between seemingly unrelated topics, and multiple students cited newfound confidence in their mathematical ideas.

Finances summary:

The income from student fees (some discounted) was $209,981.
Grant support (Jane Street, Epsilon, individual researchers) was $47,440 [some in process].
Total MathILy income: $257,421.
Administrative expenses (insurance, fliers, etc.) totaled approximately $3,173.
Total wages (instructors, PRiME, Minion, Director) were approximately $92,222.
Wage-related administrative costs (payroll taxes, etc.) were $2,908.
Travel costs (visitors, instructors) were $5,775.
Program expenses (supplies, MAA membership) were approximately $4,472.
Site expenses from Bryn Mawr were $143,519.
Total MathILy expenses: approximately $252,069.

The individual researcher NSF grants supported subsistence, stipends, and travel for trainee staff members. Jane Street funded financial aid (as did the Epsilon Fund grant) and visitor travel. We were fortunate to receive donations of software from Wolfram Research worth $5,025, and volunteer time, travel, and housing worth roughly $1,200. The net revenue of approximately $5,352 arose primarily from lower-than-budgeted costs for visitors and supplies.