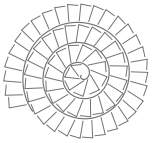

Mathematical Staircase, Inc.

MathILy-EST

MathILy-EST 2020 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. Theoretically, both programs take place at Bryn Mawr College and with all the students and staff sharing the same dorm building, but in 2020, both programs were conducted remotely online.

Program Preparations

Promotions

Emails: Announcements of MathILy-EST were sent to the {MathILy, MathILy-Er} mailing list, to multiple email lists in the professional math community, to departments and individuals at Historically Black Colleges and Universities and Minority Serving Institutions, and to other contacts.

Webpages and links: MathILy-EST has its own webpages, and of course it is listed on the NSF-REU pages. It is also listed on the Institute for Broadening Participation's pathwaystoscience.org, as well as on multiple lists of REUs, such as https://sites.google.com/view/mathreu.

Website traffic: The MathILy-EST website was the 5th most popular page at mathily.org, with 9K hits over the last year.

Other Activities: At the Joint Mathematics Meetings, sarah-marie gave a talk about selecting students for {MathILy, MathILy-Er} and how the structure of MathILy-EST accommodates students who are younger than in other REUs. Hannah and sarah-marie held an AoPS Math Jam in March, with 45 people during much of it and 60 people at the high points.

Applications and Admissions

Demographics: There were 54 fully completed applications for the 6 REU slots. Applicants originated from 22 US states (about 23 were from schools in CA, MA, PA, and IL.) The small (for an REU) number of applications is almost certainly due to COVID-19.

The data in the following table was mostly self-reported by the applicants.

Stage in application	Female and non-binary	Asian-American	African-American	Latinx	SLAC
All applicants	30%	30%	13%	2%	30%
First cut (34)	32%	29%	21%	3%	32%
Second cut (20)	45%	25%	25%	5%	35%
Short List (14)	57%	28%	14%	0%	36%
Invited	67%	17%	33%	0%	67%

Every student invited to participate accepted within a day of the invitation.

Personnel

Administrative: The MathILy-EST 2020 Director was Dr. Hannah Alpert (NSF postdoctoral fellow, University of British Columbia). 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 proposal for the grant that funds the program.
Max Engelstein, mathematics faculty at the University of Minnesota
Nate Harman, member at the Institute for Advanced Study
Thomas Hull, mathematics faculty at Western New England U. and MathILy-EST Director 2019
Peter Tingley, mathematics faculty at Loyola University Chicago

What Happened at MathILy-EST 2020?

Academics/Research

The research project was about sorting vertex labels on convex pieces of grids. It was a combinatorial problem involving asymptotic and algorithmic thinking, related to the Director's current work on configuration spaces of disks.

Reading: The first week of the program was spent on a reading assignment. The Director chose five research papers for students to read, and assigned one to each student, with the exception that one of the five papers was assigned to a pair of students. Each paper contained relevant background information for the summer's research project, which was about the "routing by matching" process on graphs. Each student gave a presentation to the other students at the end of the week.

Mathematical explorations: After the first week, research on the real open problems began, and students started staking out their goals for the rest of the program. The big goal was to show that if

you use a convex polygon to cut out a piece of the infinite grid graph, the routing number of the grid piece grows linearly with respect to the diameter of the polygon.

In Week 2, students focused on adapting an existing proof about triangles to a larger class of shapes that the group called "ramp-like polygons", and on how to cut up an arbitrary convex polygon into ramp-like pieces. In Week 4, several students got interested in rotating polygons, and figured out that it might be more helpful to shear the polygons instead. In Week 6, students took stock of what the shearing idea could accomplish and what other components were needed to prove the goal theorem, and they realized that they had a full outline for how to prove the theorem! They also simplified their approach from needing to shear three times (in order to simulate a rotation) to only needing to shear once. In Weeks 7 and 8, the goal was to outline, in as much detail as possible, a paper proving the goal theorem. Students identified and then fixed several holes in the argument. As the REU ended, the consensus was that all potential sources of trouble had been identified and that finishing the remaining few bits of math would take only a few hours more.

Writing: In general, the schedule alternated between weeks of mathematical exploration and weeks of writing up the conclusions of those explorations. The assignment for Week 3 was to write up one small theorem from the project as a "mini-paper": the theorem itself would appear exactly as it might in a journal article, and so would any prerequisite definitions and results, but there would be no abstract, introduction, conclusion, and so on. The Director had to advise most students to select a smaller and easier theorem to write up than they originally suggested, and was available to suggest corrections on drafts, but even so, every student found the writing process exhausting and had no time in Week 3 to continue the mathematical explorations.

For Week 5, everyone made a list together of all the results that had been proved but had not been written up in Week 3, and even though almost none of the results got to a completely final version during Week 5, the students were able to work about twice as fast as in Week 3, having learned the basics of what was required. In Week 7, writing started off with a big meeting to decide what the sections of the paper would be, and then students were asked to write, in paper-appropriate wording, all the theorem statements and lemma statements that would appear in the paper. Once the theorem and lemma statements were in place, the task of filling in the rest of the paper could be worked on in small pieces at a slower pace, after the REU was over.

Presentations: The MathILy-EST students had to make many 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. Sometimes the students talked more formally, with topics in the order they had prepared, and sometimes they skipped around according to the questions of the visitors—some visitors were able to stay for only half an hour, so those visitors made sure to ask questions in order to see topics in an order that was intuitive to them. The MathILy-EST students found it very interesting to hear the thought processes of these expert mathematicians trying to understand their project for the first time, in just a few minutes.

During the last week of MathILy, the MathILy-EST students gave a Daily Gather to the MathILy students on the topic of their research. The MathILy-EST students decided not to say anything about the actual proofs they had worked on during the summer, instead asking the MathILy students to do a task that had already been known before the summer began, but that had the same flavor as the MathILy-EST work. As a result of multiple days of planning and rehearsing, the Daily Gather went very smoothly, exactly as the MathILy-EST students had envisioned it.

In the last week of MathILy-EST, the students started preparing for presenting at the Joint Mathematics Meetings in January 2021. Three students would prepare a 25-minute talk for the undergraduate talks session, and the other three students would prepare a poster for the undergraduate poster session.

Professional Development

Software: Students learned a lot about LaTeX skills, such as how to use TikZ, Beamer, and BibTeX. All of students' LaTeX work was done using Overleaf. They also found GeoGebra very convenient for making more precise figures than they could draw freehand, which was often relevant while exploring the mathematics in the project. They made daily use of Coauthor, Erik Demain's open-source discussion board software for mathematical collaborations. Students also used software already familiar to them, including writing code in Python and making pictures in Illustrator.

Other professional development: The MathILy-EST students were guided to write their own professional CVs, and heard about graduate school in two different sessions, one of which was a panel discussion by the MathILy staff who had been to graduate school in math. There were also professional development seminars on writing papers, giving presentations, how to use library databases to look up journal articles, ethics in research and mathematics, math opportunities for undergrads, and how to file a personal income tax return. MathILy-EST attended MathILy Life Seminars, and were particularly interested in the panel discussion on careers in mathematics.

The Online Environment

Software tools: MathILy-EST met on Zoom, using the MathILy Zoom subscription. Every weekday, MathILy-EST had a four-hour meeting, offset two hours later than the MathILy morning class, and students were asked to schedule themselves to work for three hours individually. MathILy-EST students frequently used the screen share and whiteboard functions in Zoom, often with annotations from various other members of the group. The students reported that they missed being able to have conversations at in-person boards, and those who had stylus input (either on an iPad or on a drawing tablet) said that it was very important for their ability to talk in real time about math. MathILy-EST was also part of the MathILy Slack workspace.

Social activities: MathILy-EST students typically met for an hour or so on the weekend for bonding activities that they planned themselves, including online games. At one point, a group of MathILy students wrote a puzzle game that the rest of the MathILy community could attempt in teams, so MathILy-EST formed a team and solved several puzzles together.

Post-Processing

Post-program senior personnel meeting: Near the end of the program, there was a meeting to discuss the program and to plan for next year. Max Engelstein agreed to direct the REU in 2021.

Impact: In a post-program survey, all six participants stated that participation in MathILy-EST has positively influenced their career path or career. The free-answer followups about how MathILy-EST

has positively influenced them included several variations on the program providing them with certainty or confidence that continuing the study of mathematics is the right path for them. When the MathILy students were surveyed, almost all felt that MathILy-EST was at least somewhat valuable to their MathILy experience, both in general and on every specific aspect queried.

Finances summary:

The income from grant NSF DMS-1851842 was $32,523.

Total MathILy-EST income: $32,523.

There were no separate administrative expenses.

Total stipends (director, participants) were $28,330.

Total wages (MathILy director and Minion) were $1,732.

Total non-wage employee expenses were $150.

Program expenses (t-shirts) were approximately $150.

Meal stipends were $2,400.

Total MathILy-EST expenses: $32,762.

The approximately $239 in overage comes entirely from expenses that are not covered by NSF funding.

Note that there is still travel money in the grant budget that will be used to help students defray costs of attending the Joint Mathematics Meetings in January 2021.