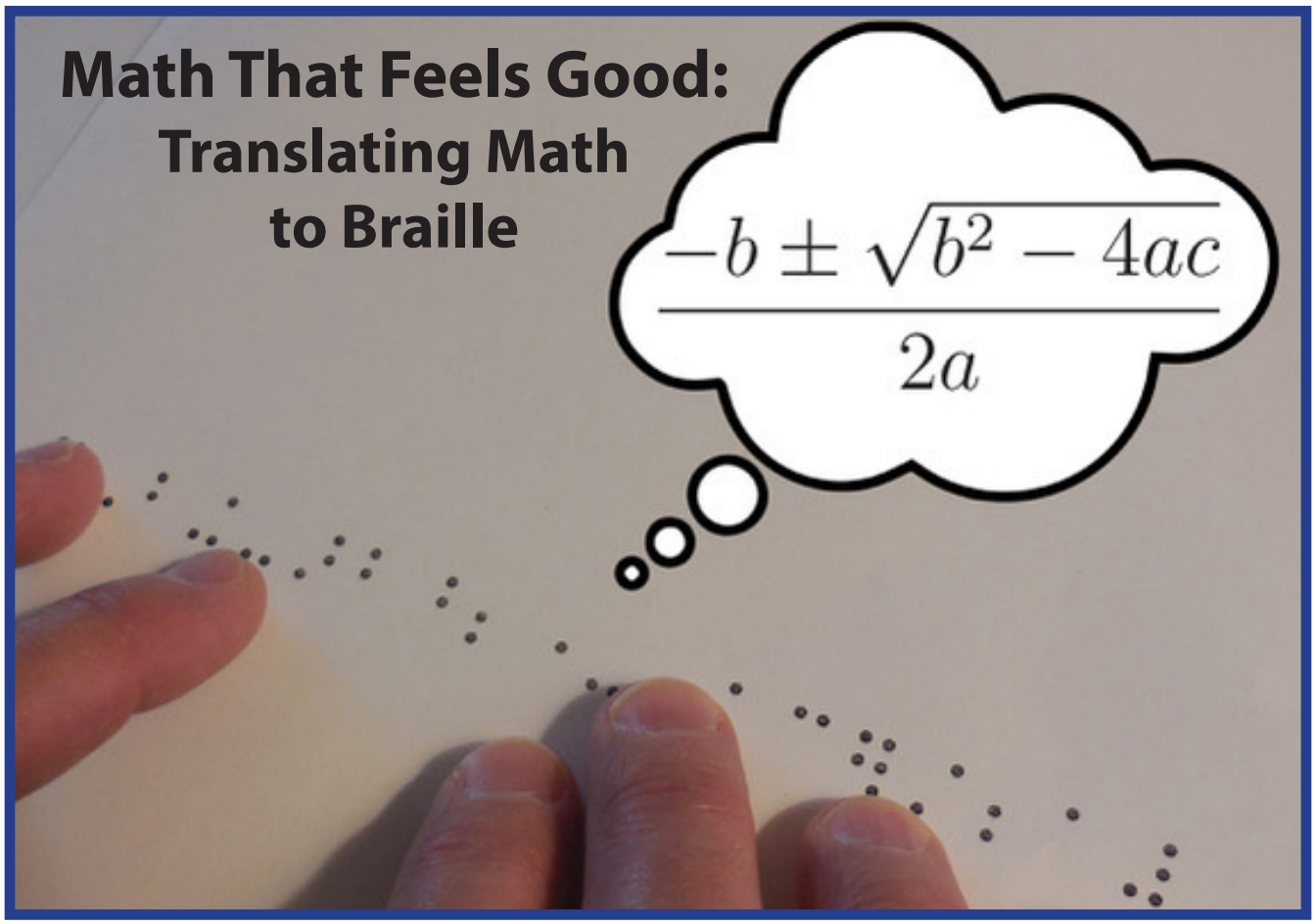
Autumn 2020

AIMatters

Newsletter of the American Institute of Mathematics



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Dynamics, Data, and the Pandemic

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2020 Alexanderson Award
Announcing This Year's Recipients

Letter from the Director

Reflections on 2020

Greetings from San Jose! This has been a most challenging year. However, we received good news in January that we were awarded a new NSF grant for five more years as an NSF-funded Math Research Institute. The award of $16.5 million officially began July 1, 2020. We are grateful to the Division of Mathematical Sciences at the NSF for their ongoing support.

We are delighted to announce our 2020 Alexanderson Award winners, Laura DeMarco, Holly Krieger, and Hexi Ye, for their brilliant work, "Uniform Manin-Mumford for a family of genus 2 curves," which appeared in the Annals of Mathematics. However, I'm sorry to say we will not have a public lecture and award ceremony this year as things still have not opened up. In fact, AIM has had no visitors since the week of March 16, due to the pandemic.

It took us a little while to figure out what to do. But now I feel like we are back on track hosting productive virtual meetings for our workshops and SQuaREs. We have found software – Sococo – that gives the feel of being in a meeting space with offices for everyone, lecture rooms, other breakout rooms, and a Happy Hour room for relaxing, socializing, and playing games. We are able to leave documents and links on tables in the various rooms. This allows us to set up a library with the papers and references relevant to a workshop and use tools such as shared Whiteboards and Zulip chat. We record all the lectures and have a link in the lecture room to all the past videos. We found that after using Sococo, it felt like we were physically in the virtual office space.

We also provide stipends for participants so that they are better able to participate in what is very much like a traditional AIM workshop, with two morning lectures followed by moderated problem sessions and collaborative small-group work in the afternoons.

We ran a 6-week summer school/internship program for 40 graduate students this summer in a large Sococo space. There were ten faculty, six mentors, and postdoc assistants. The topic was, appropriately enough, modeling COVID-19.

One thing we've realized is that a virtual space such as Sococo can be useful for a long-term research program with weekly seminars and working groups. It provides an infrastructure that is useful, we believe, even in "normal" times. Consequently, for the groups that organize in Sococo, we agree to keep their particular space (we make a new space for each group) going as long as it is of use to them.

Our call for proposals has just gone out. Until November 1, 2020, we will be accepting proposals for virtual workshops, virtual SQuaREs, and a new program called AIM Research Communities (ARCs). An ARC would include a virtual space for up to 70 people with the idea that there is ongoing weekly activity taking place but perhaps not as intensively as a week-long workshop. ARCs might be suitable for a wide range of communities, and we hope that we get some interesting proposals for these.

Despite all the challenges of this year, we are proud to share how AIM has adapted, and hope that you will consider participating in a grogram with us soon. ■

Brian Conrey

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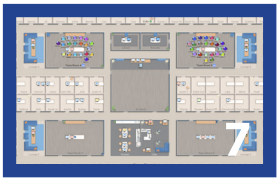

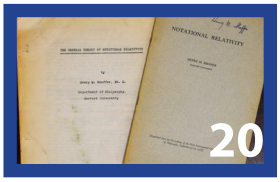

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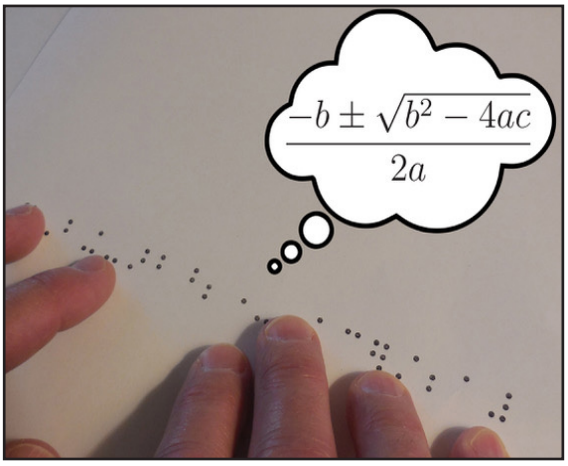


ABOUT THE COVER IMAGE

This shows the quadratic formula in Braille. Converting mathematical formulas into Braille has recently been made much easier. Read about it on pages 12 and 13.

Dispatches from Morgan Hill

Math Enrichment Moves Online Due to COVID-19

The 2019-2020 school year ended like no other for Morgan Hill Math, when we had to adapt to distance enrichment. Morgan Hill Math is an outreach program sponsored by AIM, which provides free math enrichment activities to about 300 students each year, who live in or near Morgan Hill, Calif.

Due to the COVID-19 crisis, some of our programs were cut short, new opportunities were offered and embraced, and upcoming programs may need to be put on hold. Our Fall 2019 programs, Mathletics, MathCounts6, and the MATHCOUNTS recreation training were all unaffected. This year's MATHCOUNTS Chapter competition was held pre-shutdown. However, the MATHCOUNTS State competition had to be reconfigured. Happily, most of our students were able to complete all five of the Math Olympiad contests.

Most families are introduced to Morgan Hill Math through Mathletics and MathCounts6. By working with the Morgan Hill Unified School District in the spring of 2019, advanced math students in third through fifth grade were identified and invited to try out for a spot in the Fall 2019 math enrichment programs. Last fall, our youngest students, fourth- and fifth-graders enrolled in our eight-week Mathletics program, enjoyed lessons that included learning to play Sudoku and KenKen; discovering pi; exploring angles, areas and perimeters; and practicing problem solving strategies such as working backwards, making lists, and making tables. Students in MathCounts6 were introduced to more advanced problem-solving concepts including counting in other bases, problem posing, proportions, permutations and combinations; all skills that are necessary for successfully competing in the MATHCOUNTS competition series.

The cornerstone of the Morgan Hill Math program has always been training for and competing in MATHCOUNTS. Last year, MATHCOUNTS training was available at five local Middle Schools —Britton, Charter, Jackson, Murphy, and Oakwood. In 2019, over 75 students, from eight local schools, trained with me once a week, from September through December, sharpening their skills in counting, series and sequences, probability, permutations and combinations, functions, algebra, and geometry. In January, 51 students came together and continued to train all together, to prepare for the chapter competition. These sessions were held at Ann Sobrato High School, where older students who had previously competed in MATHCOUNTS volunteered to help coach these mathletes.

Morgan Hill students competed in the

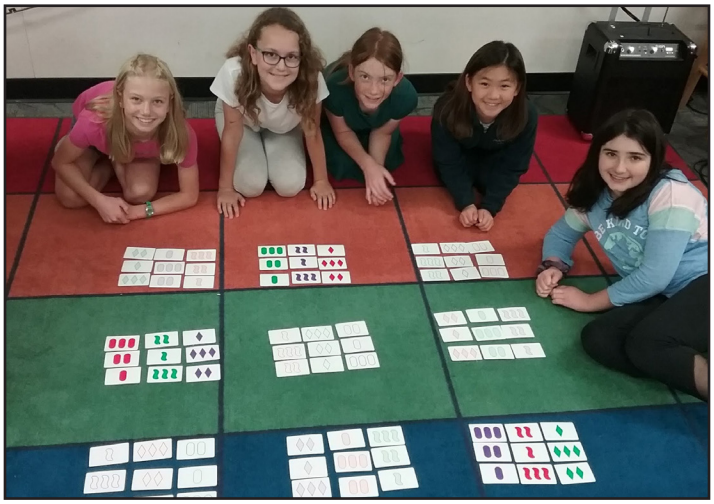
A Morgan Hill Math Mathletics class.

MATHCOUNTS Coyote Valley Chapter Competition, held in Morgan Hill, on February 1, 2020. This year's competition was fierce! Oakwood School ended Martin Murphy's three-year reign by beating them in the team round. Charter School came in second and Murphy was third, with less than a point separating the three teams. The four students from the Oakwood team, as well as Henry McNamara from Charter and Roma Shah from Murphy, who came in First Place and Second Place in the Individual Rounds, qualified to compete in the Northern California MATHCOUNTS State Competition to be held at Stanford, on March 23. These six students were so excited to compete at the state level! However, the CA state competition was not

to be. The statewide shutdown cancelled the in-person state competition.

Two local schools competed in the weekly Math Madness competition in the fall of 2019: Sobrato High School and Martin Murphy Middle School. As a joint initiative between American Mathematics Competitions (AMC) and AreteLabs, Math Madness is emerging as one of the premiere math competition events in the United States. Murphy did very well by making it to the finals in their division!

In the fall, enthusiastic students from grades



Students from a MathCounts6 class complete the SET universe!

four through eight were invited to participate in the Math Olympiad for Elementary and Middle School (MOEMS). From November to March, over 125 kids were challenged to strengthen their problem-solving skills in this once-a-month, five-question test. Most of the Morgan Hill Math students were able to complete all five contests before the shelter-in-place started. One Morgan Hill student, Henry McNamara, won the George Lenchner Medallion for achieving a perfect score in the Middle School division! Only 0.5% of the nearly 170,000 participants received this award.

Our Middle School and High School Mathletes participated in several other competitions this year. All students involved in the weekly MATHCOUNTS training classes, as well as interested fifth and sixth graders, took the AMC8, an MAA competition for students in eighth grade and below. Many of them also challenged themselves and joined high school students in taking the AMC10 exam. By scoring in the top 2.5% in the United States and Canada on the AMC10, two local students, Neil Shah (10th grade) and Ethan Fang (9th grade), qualified to take the American Invitational Mathematics Exam (AIME), which is the first in a series of examinations that culminate with the International Mathematical Olympiad (IMO). Several students took the four-hour Bay Area Math Olympiad in February. And two teams of six students competed in the online Purple Comet! Math Meet.

The Math Club from Live Oak High School held a Math Mardi Gras for third-grade students who attend Barrett Elementary School. These high-schoolers had a wonderful time working with the third-graders and leading them through math activities. The youngsters enjoyed exploring the games and earning Mardi Gras beads for their accomplishments. It is so heartwarming to see these Morgan Hill Math alumni giving back to their community and spreading the joy of math to Morgan Hill's future mathletes!

The Morgan Hill Math Teachers' Circle is still growing. Local math teachers in any grade can attend monthly meetings to explore rich math problems, rediscover the joy in learning math, and network with fellow teachers and mathematicians. Meetings were held on the last Wednesday of the month, at the Morgan Hill Community and Cultural Center. We were able to hold five meetings over the course of the school year where we delved deeply into several Julia Robinson Math Festival (JMRF) activities such as Random Walks, Puppies and Kittens, and Cup Jumping. We also explored non-Euclidean geometry by constructing Hyperbolic soccer balls, and compared the game of Criss Cross to Platonic solids. The Morgan Hill Math Teachers' Circle is part

of the Bay Area Teachers and Mathematicians (BATMath) Network.

The whole world changed this past spring. Suddenly all the students were at home. Teachers were learning how to teach remotely. Parents were learning how to homeschool. Families were desperate for additional activities. The online math community responded wholeheartedly!

The MATHCOUNTS Coyote Valley Chapter Competition is about to begin.

The Morgan Hill Math website now has a Math Activities page with links to multiple online activities. Math Olympiad provided two problems a day for the first six weeks of the shelter-in-place that were forwarded to interested families. There are links to the JRMF games that are being highlighted each week. KenKen puzzle sets are updated weekly. And AIM's **mathcommunities.org** site is available.

The most popular new program came from AreteLabs, who coordinated a free online math meet. Over 70 Morgan Hill Math kids competed with thousands of other kids in either the Elementary or Middle School division. We competed against teams from all over the country, every week. After each match, I held a Zoom meeting to go over the questions and solutions. When the official tournament was over, the students wanted to continue. So we held weekly competitions between the Morgan Hill teams.

Some students also joined me in May for MATHCOUNTS mini lessons, where we watched videos and completed worksheets provided by MATHCOUNTS. Since the MATHCOUNTS State Competition had to be cancelled, The Art of Problem Solving website held a MATHCOUNTS Week where everyone was invited to take the competition online.

We do not yet know what the remainder of the 2020-2021 school year will look like. Our Mathletics, MathCounts6, and MATHCOUNTS classes are usually held in borrowed classrooms after school. These programs may need to be reconfigured to go online, or put off for a few months. Morgan Hill Math will adapt, just like all of us have, and will continue to provide math enrichment for our future mathematicians, engineers, doctors, researchers, and more. ■

– Kelley Barnes

Competitors from the 2020 MATHCOUNTS Coyote Valley Chapter Competition.

Taking AIM at COVID-19
Dynamics, Data, and the Pandemic

Over forty graduate students and advanced undergraduates participated in an online summer program to study dynamics and data in the COVID-19 pandemic. The program was sponsored by AIM and the NSF.

Students had the opportunity to learn the basic mathematical epidemiology underlying the models used in studying COVID-19 using a dynamical systems perspective. The first three weeks of the program were focused on getting the students up to speed on the mathematics of the modeling. During the first week, possible research questions were identified. The second week was devoted to understanding the models better, and the third-week emphasis was on data. The faculty leaders designed many interesting activities to help students get ready for the actual research. For example, in Week One, an afternoon was devoted to a role-playing session where two students played the role of policymakers and another two acted as scientists.

Sococo virtual offices.

To help structure the activities and give a sense of belonging, the summer school used a virtual office space called Sococo. An image is provided so the reader can see the layout. Each participant had an office. There were meeting rooms, an "all hands on deck" room, a library, a kitchen, and even a cafe. Often everyone would meet in the "all hands" room, and then break up into smaller groups that worked in a meeting room or an individual office. Sococo allows one to start a Zoom meeting in a room, write together on a whiteboard, post links to materials, chat, watch a movie, or have a session of tai chi together.

The fundamental model of epidemiology is called the SIR model. The population of interest is subdivided in three groups, or compartments, of individuals: Susceptibles (S), Infected (I), and Recovered (R); each individual is in some compartment. An epidemic is then thought of as a flow through the compartments, from S to I to R. There are variations of the SIR model, as well as other models that involve stochastic approaches, network approaches, and agent-based models, where the behavior of each individual separately is taken into account.

The students were guided by ten faculty from universities around the country: John Gemmer (Wake Forest), Sarah Iams (Harvard), Hans Kaper (Georgetown), Richard McGehee (Minnesota), Nancy Rodriguez (CU-Boulder), Steve Schecter (NC State), Mary Silber (Chicago), Erik Van Vleck (Kansas), Mary Lou Zeeman (Bowdoin), and the program director, Christopher Jones (UNC-Chapel Hill). They were supported by five mentors, who are junior faculty, postdocs, or advanced graduate students: James Broda (Bowdoin), Punit Gandhi (Virginia Commonwealth), Kaitlyn Martinez (Colorado Mines), Christian Sampson (UNC-Chapel Hill), and Maria Sanchez-Muñiz (Minnesota). Critical to the effort was a panel of experts, most of whom are mathematical epidemiologists, but also included a statistician, a medical expert, and two health industry researchers: Linda Allen (Texas Tech), Pauline van den Driessche (UVic), Nicholas Ma (Cerner), Cordelia McGehee (Mayo Clinic), Andrew Roberts (Cerner), Jianhong Wu (YorkU), and Abdul-Aziz Yakubu (Howard).

After the initial three weeks of listening to lectures, videos and multiple discussions, the research was divided into five overarching areas. Students then formed into groups studying smaller subtopics.

On the following pages, there is a list of the topics and a short description of the goals of the smaller groups.

1. DISEASES AND THE ENVIRONMENT

Climate:

The research focus was to use multiple metrics to try to quantify decreases in carbon emissions over the course of 2020, with specific emphasis on the impacts caused by the pandemic.

Air Quality:

The group investigated the relationship between COVID-19 transmission and air quality. One theory on the transmission of the virus suggests it is suspended in aerosolized particles, which include pollutants.

Zoonotic Spillover:

The goal of this group was to study "zoonotic spillover," the process by which diseases are transmitted from animals to humans. Zoonoses are emerging (and re-emerging) all the time, and although they rarely develop into global-scale pandemics, they frequently cause epidemics and constantly pose a major public health problem.

2. IMPACTS OF BEHAVIOR

Adaptive Network Models:

This project investigated how time-varying compliance with interventions alter the structure of contact networks, and what effects this has on the overall trajectory of the epidemic. More specifically, can the risk-taking behaviors of neighbors affect the behaviors of an individual?

Poletti Model (SIR and Game Theory):

The effectiveness of public health interventions during pandemics depends on how people respond to them. This group studied the dynamics of public behavior in response to perceived risk, policy changes, disease severity, and social pressure.

3. INCORPORATION OF DATA

Multiscale Modeling Group:

Epidemiological models and COVID-19 data exist on various spatial scales ranging from intra-host mechanisms to global viral spread. This project's goal was to create a scheme to incorporate various data streams into a multiscale epidemiological model of inter-host dynamics.

Topological Epidemiology Group:

This group asked whether tools from topological data analysis and statistics can be used to understand the relationship between the geometry of the pandemic data and the properties of the virus. Special questions, such as the seasonality or the rate of transmission, can be seen in this data, but only under the correct lens.

Population Risk Index (Blood-Type Group):

The goal of this project was to create a population-level index that could quantify the susceptibility of individuals with different blood types to becoming infected or dying from COVID-19. The population-level risk index, or PLR, should be dependent on the prevalence of comorbidities, blood types, and other genetic characteristics in a population.

4. RESOURCE ALLOCATION

Optimization of Pop-up Test Site Locations:

This group focused on question of where to place pop-up test sites in an area where the disease is spreading so as to maximize the numbr of people tested and stay within funding constraints.

Optimal Control:

When institutions plan to reopen, they must consider the possibility of a rebound in COVID-19 cases nationally. In order to find and sequester emerging cases in a population, it is vital to have an effective strategy for testing members of the population. The focus was a compartment model on a static network with the goal of minimizing the tests needed to keep deaths and infections below a certain threshold.

Group Testing:

This team examined network-informed group testing strategies for COVID-19 surveillance among members of a closely interacting population (e.g., a soon-to-be-open college). Group testing consists of pooling multiple patient samples into a single test to maximize case identification while minimizing the number of tests which need to be performed. Informed group-testing strategies use individual disease risk profiling to further optimize group-testing efficiency.

Image: WarmWorld/Shutterstock.com

5. SOCIAL JUSTICE

Economy and Disease Interactions:

This group focused on coupling population health and economic impact as regulatory mechanisms with a stay-at-home intervention strategy during the COVID-19 pandemic. In particular, they analyzed the extreme responses—consider only the economy or only the number of cases (think Sweden vs. New Zealand)— as well as a regulatory feedback response that attempts to minimize labor lost in all ways through various prioritization schemes of health and the economy.

Interpopulation Competition with Applications in a Two-Population SEIR Model:

A possible proxy for modeling racial disparity is to use age stratification in data assimilation in the study of COVID-19 spread within a single urban population. The model focused on the population of a single urban center, which was chosen based on both the diversity of its inhabitants and the availability and reliability of COVID-19 case-related, age mixing, and overall mobility data.

Insured/Uninsured:

As legislators and others in the U.S. have publicly argued for the need for full health insurance coverage during this pandemic, it is natural to want to know the role the uninsured population plays in driving a pandemic. For example, does the uninsured population have a disproportionate toll on ICU bed capacity? What about the death rate? This group used simulation, visualization, and interesting ways of assimilating data to create a mathematical profile of the overarching question.

Multipopulation Models:

The COVID-19 pandemic caused by SARS-COV-2 had a historic impact worldwide. This impact has varied in intensity according to the location and the population that has been affected. Minority populations have been greatly affected because they have other variables such as the social determinants of health that have aggravated the situation for these specific communities. Based on a model for two populations developed by Cordelia McGehee, the project explored which parameters are more sensitive, how the epidemic behaved in the population when manipulating these parameters, and the possible repercussions on society. ■

– Estelle Basor

This summer school was funded by the National Science Foundation (NSF). We are grateful to NSF for their rapid response in supporting COVID research, their continued support of our research programs, and their commitment to broaden the mathematical community.

Summer School
Student Spotlight

Forty-one advanced undergraduates and graduate students participated in the AIM Summer School. They were chosen from over 550 applicants and they were a motivated, dynamic, and hard-working group of students. One of the students was Tayler Fernandes Nunez, whom we interviewed at the end of the school.

Tayler was a member of the five-person Age-structured Population research group, which studied the question of how COVID-19 spreads between two populations based on age range. Her research group focused on the population of the state of Illinois, which was chosen based on both the diversity of its inhabitants and the availability and reliability of COVID-19 case-related, age mixing, and overall mobility data.

Tayler Fernandes Nunez

We asked Tayler her thoughts on the Summer School and working in a virtual world. She said the work was both exciting and exhausting, but that she especially liked the freedom to be able to ask lots of questions of her fellow researchers to sort out the issues that came up. She enjoyed the online tai chi sessions and the mentorship of the leaders. Taylor also remarked that the team developed a strong friendship in their six weeks of work. Their team name was "Best Friends Club."

We also asked her thoughts about the virtual office space, Sococo, which provides a sort of blue print of an office space with lecture halls, meeting rooms and offices. Tayler replied that it provided structure and allowed for a mental transition when switching tasks.

Tayler had the opportunity last year to attend a Research Experience for Undergraduates (REU) program that had a pure mathematics emphasis. The summer school with the focus on modeling aspects of a pandemic was quite the opposite. She said that she really enjoyed "being grounded in the applied mathematics" and may pursue that direction in graduate school.

Tayler received her undergraduate degree in mathematics from Northeastern University this past May. This fall she will attend the Postbaccalaureate program at Smith College and will then enter a PhD program the following year. ■

– Estelle Basor

CALL FOR PROPOSALS

We are seeking proposals for virtual activities to take place in 2021.

- **AIM Virtual Workshops are collaborative activities for 20-30 people, focused on a specialized area of research mathematics.**
- **AIM Virtual SQuaREs are collaborations of 4-6 people, focused on very specific research problems.**
- **AIM Research Communities are larger collaborative efforts, typically involving 40-60 researchers, organized around a particular specialty area of the mathematical sciences.**

For more details and online applications:

www.aimath.org

Application deadline: November 1, 2020.

Summer School
Project Spotlight

The summer school projects were divided into five overarching areas and then each subdivided into smaller topics. These ranged from examining the set up of testing sites, to the study of the uninsured in the spread of the pandemic, to the role of air quality as a factor in the spread of COVID-19. Here is a highlight of one of the projects that investigates the effects of university scheduling on the surrounding community, a topic that is of much current interest.

How would changing the class schedule of university students affect the spread of COVID-19 in the surrounding community? This is the kind of question considered by Elijah Pivo, Colin Roberts, and Claire Valva. For example, if half of the students attend in-person classes one week, and then go online the following week, while the other half of the students do the opposite, will it help reduce the number of infected individuals in the surrounding community? Or what happens if students are only in class with students of the same major, thereby reducing the number of contacts? These are important and timely questions as universities and schools try to navigate the reopening of their institutions and have concerns about the effect on the cities where the universities are located.

Given the complexity of disease spread, as well as the growing availability of data, the team proposed a multi-scale framework, in conjunction with data assimilation techniques, to investigate the viral spread of COVID-19. The multi-scale framework was a combination of agent-based modeling, where each person is modeled individually, combined with an approach where individuals are compartmentalized.

For example, using Fort Collins, Colorado, and Colorado State University, they derived the contact rate within the university from the agent-based model, and the contact rate within the greater city from parameter estimation from current Fort Collins COVID-19 infection rates.

Their preliminary results, among a variety of interesting findings, predicted that increasing the number of in-person classes (periods) attended each day increases the contact rate in a linear fashion, and that staggered schedules did indeed "flatten the curve" for the surrounding city.

These techniques can be applied to many other situations including workplaces and K-12 classrooms. The group plans to improve their models, publish their results, and then make the work available to others.

Elijah Pivo received his undergraduate degree from Johns Hopkins University in Electrical and Computer Engineering and is beginning a PhD program at the MIT Institute for Data, Systems and Society.

Colin Roberts is a fourth-year PhD student at Colorado State University, where he also received his undergraduate degree in Mathematics and Physics.

Claire Valva received her undergraduate degree from the University of Chicago majoring in Geophysical Sciences and Mathematics and is entering the PhD program at the Center for Atmosphere Ocean Science at the Courant Institute for Mathematical Sciences. ■

– Estelle Basor

From left: Elijah Pivo, Colin Roberts, and Claire Valva.

Math That Feels Good

Translating Math to Braille

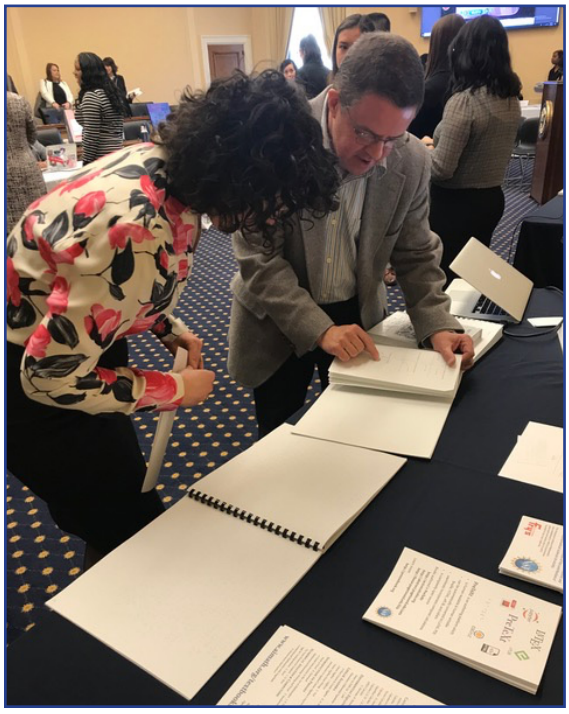
Highlighting the contributions of the mathematics community to the public is central to AIM's mission. In March, shortly before the COVID-19 shutdown, AIM Director of Programs David Farmer had the opportunity to present to the House Committee on Science, Space, and Technology. The presentation took place in the Rayburn House Office Building in Washington, D.C. The Rayburn Building has offices for members of the U.S. House of Representatives, as well as a hearing room for each of the standing House committees.

The theme of the program was "Broadening participation in STEM." Six principal investigators of National Science Foundation grants were invited to give threee-minute presentations. Farmer's talk described recent work on the automated production of Braille math textbooks, a natural extension of the PreTeXt Project, an NSF-funded platform for producing open textbooks.

For someone more familiar with talking in a math seminar or at a math conference, this was completely different. The most obvious difference was that the presentation could not be accompanied by slides or by writing on a blackboard. The NSF staff who helped the speakers prepare for the presentations explained it as, "You have to do this Washington style: just stand at a podium and talk." The three-minute time limit meant that the exact wording had to be planned in advance: it was not sufficient to have a general outline and then just talk extemporaneously.

Following the presentations was time for informal discussions. Presenters stood beside tables displaying material about their project and their institution. In some sense, this was like the exhibit area at the Joint Mathematics Meetings, but there was one big difference: nobody wore a name badge. When people approached the table, it was not easy to tell if they were Congressional Representatives, staff members, interns, NSF representatives, or members of another government agency. ■

– Sally Koutsoliotas



Left: David Farmer presents. Above: Farmer discusses Braille textbooks with Karen Marrongelle, Assistant Director of Education and Human Resources at the National Science Foundation.

The text of the presentation to Congressional staff

The American Institute of Mathematics, which we call "AIM," is one of eight math research institutes in the U.S. funded by the NSF Division of Mathematical Sciences. The work I want to tell you about was conducted by faculty from several universities, but it is institutes like AIM that make such work possible, by bringing together the right group of researchers and providing the infrastructure to foster collaboration.

I am holding up the book *Abstract Algebra: Theory and Applications* by Tom Judson, who is a math professor at Stephen F. Austin State University in Texas. This is a textbook for a standard upper division math course.

And now I am holding up a Braille version of that book. Actually it's only Chapter 2 (out of more than 20 chapters), because Braille takes up a lot of space.

One of the special things about this Braille version is that it was produced automatically from the same source as the printed version. Prior to our work, the creation of most Braille textbooks was a lengthy and labor intensive process. Commercial publishers don't produce Braille books: it comes down to the university or the school district commissioning someone to do that work. And once they do it, copyright law prevents them from sharing it. But now we have a free alternative.

Grants from the NSF Division of Undergraduate Education have enabled us to create a new system for writing textbooks and other technical documents, where you can output to any format once the book is written. We have print and Braille, and also EPUB and online Web versions. The online version looks good on a smart phone, so students can have their textbook with them at all times. When the next new format is invented, we will be able to convert to that, too.

Support from the NSF was absolutely instrumental in making this work possible, and I'd like to point out a couple of particular features.

The first is that we had support from both the NSF Division of Mathematical Sciences, and the NSF Division of Undergraduate Education. Each Division supported research that separately led to innovations which in combination produced the system that enabled us to automatically produce Braille.

The second is that this work was made possible by theoretical advances. Theoretical work enables you to simultaneously solve an entire class of problems in one go. Our new system can convert to any format, such as Braille, because we had a theoretical grasp of the problem. Sometimes theoretical advances can be difficult to appreciate, especially when only a limited number of people can understand it. But our work on the Braille conversion shows the kind of payoff that is possible when you have done the theoretical groundwork.

I am happy to show you more about these textbooks during discussion time.

Thank you. ■

Virtual MTC Workshop

Bringing Teachers Across the Nation Together

This July, the Math Teachers' Circle Network and AIM hosted a virtual workshop to offer free professional development and online experience to K-12 teachers throughout the nation.

Over 250 teachers participated in the workshop, attending from all around the U.S. and several foreign countries. Each day had between 6 to 7 different sessions, led by teachers and leaders of the Math Teachers' Circle community. Attendees signed up for the sessions that felt applicable to them but were welcome to jump in and out of sessions to better fit their schedules.

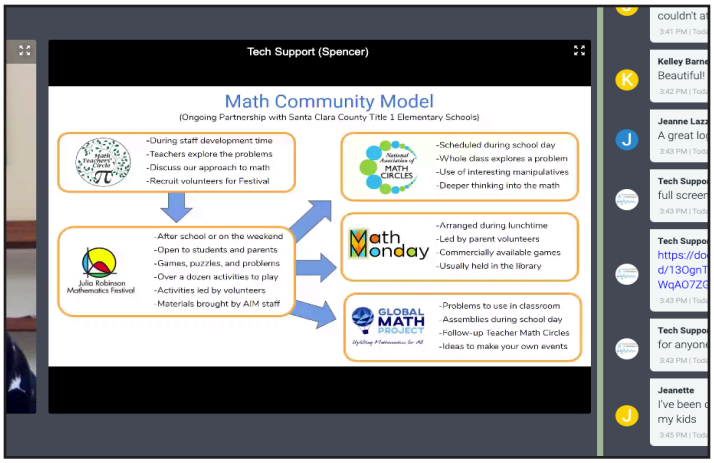
Each day included a full menu of sessions focused on mathematical topics like *The Game of Life* and *Perfect Rulers*. As with in-person Math Teachers' Circle sessions, participants could switch between listening to presentations in webinar style and working together on the mathematics at small-group tables. Additionally, each day we hosted a "Teachers' Lounge" seminar, with topics ranging from interactive online teaching to equity in mathematics education. The workshop also offered daily opportunities to build community amongst teachers, including morning Zumba, and a Social Circle in the afternoon during which teachers played games like Estimathon and Math Jeopardy. Other highlights included a special screening of the documentary *Navajo Math Circles* (with a follow-up Q&A with filmmaker George Csicsery and project founder Tatiana Shubin) and a closing talk on *Pile Splitting* by Global Math Project founder James Tanton.

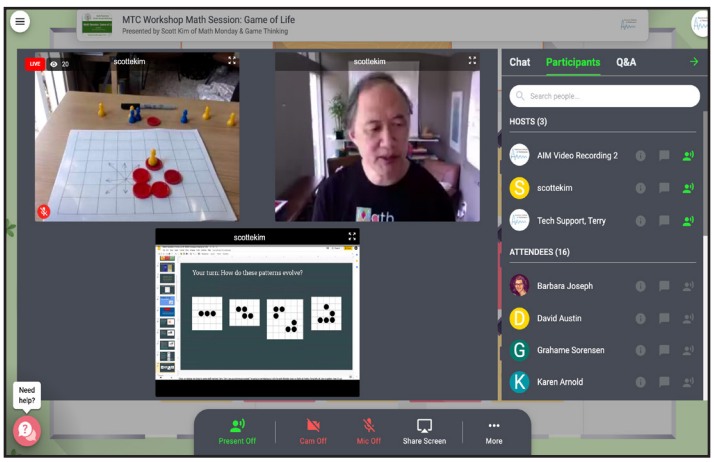
The workshop evolved from a series of Math Teachers' Circle Network online sessions organized this past spring. Several of the presenters in that series, representing multiple Math Teachers' Circles in three states, reached out to AIM with the idea of organizing a week-long experience in order to better support teachers facing the likelihood of online teaching this fall semester. Several of these organizers hosted a session solely dedicated to online teaching, which had over a hundred participants.

AIM and the Math Teachers' Circle Network used the feedback from this workshop to prepare for the fall semester, when we are offering a regular schedule of online programming to help teachers and families find joyful math experiences. This will be a part of the Math Communities effort and can be found at MathCommunities.org. All of the workshop sessions were recorded and are readily available to those in need of ideas for online teaching.

These videos and a recap of the workshop can be found at **mathcommunities.org/teachers-online-workshop/.** ■

– Spencer Bowen and Brianna Donaldson





Left: AIM staff present on how Math Teachers' Circles connect with other programs. Right: Scott Kim facilitates a session exploring John Conway's Game of Life.

First AIM Virtual Math Festivals

Online Math Fun for Students

On Saturday, May 9, 2020, over 70 fifth- through eighth-grade students from Santa Cruz County participated in AIM's first ever "Virtual Math Festival."

As a response to the COVID-19 pandemic, the festival was hosted entirely online, taking place in a virtual event hall where students could freely come and go between tables, choosing the activities that felt most engaging to them. Activities were adapted from Math Circles and the Julia Robinson Mathematics Festival, with an eye toward recreating key aspects of the in-person festival experience while also taking advantage of the online format. In particular, virtual manipulatives created by AIM allowed students to explore and collaborate on activities using files that are easily shareable with teachers through their Google Classrooms and available to anyone online through mathcircles.org.

Similar to an in-person festival, the Virtual Math Festival featured half a dozen different games and activities that let students play and experience the fun side of mathematics. Problems were highly accessible, so students could work on any activity, but as they explored deeper into problems, they would discover more interesting mathematical concepts. Each activity was led by an adult volunteer who guided students through the problems by asking insightful questions or offering helpful avenues of exploration. The more than 20 volunteers consisted of K-12 teachers from Santa Cruz schools as well as members of the UC Santa Cruz's Monterey Bay Area Math Project and Cal Teach program.

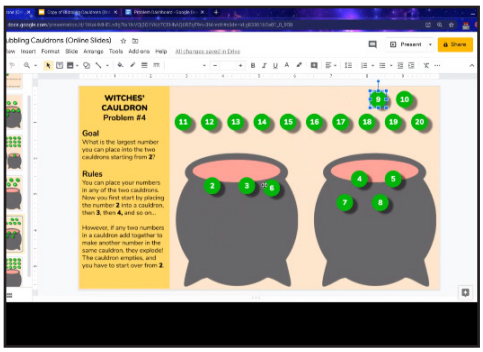
This festival was a collaboration with the Santa Cruz County Office of Education. Superintendent Dr. Faris Sabbah was in attendance and kicked off the festival with a welcome message to the students, who represented over a dozen of the county's schools. Santa Cruz County Office of Education Math Coordinator Kevin Drinkard was one of the primary organizers of the event, recruiting students and teachers. After receiving positive feedback from the festival and requests for more online events, he hosted a week-long virtual summer camp for 26 middle school students as well as four college student counselors. This camp was also made possible by AIM's online events hall and math activities.

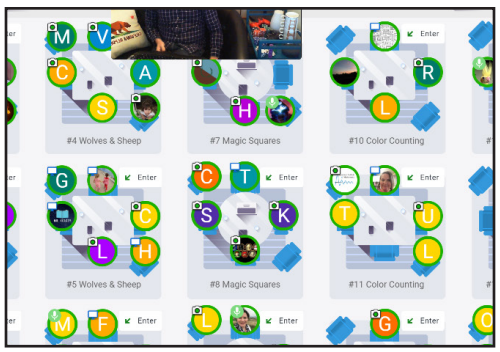
Additionally, as part of its partnership with the Santa Clara County Office of Education to bring math outreach events to Title 1 schools, AIM hosted a second Virtual Math Festival for schools in the Berryessa Union School District on Wednesday, May 27th. This festival, which served another 70 middle school students with help from a dozen Santa Clara County public school teachers, was a successful pilot test for the County's efforts to bring online events to schools in the fall as they begin the school year remotely.

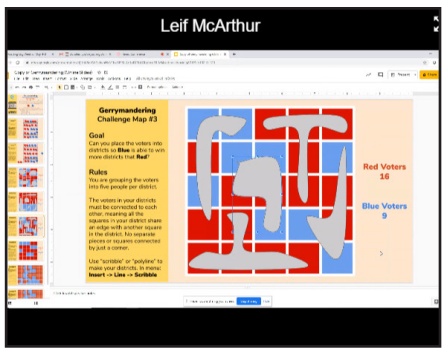
AIM looks forward to supporting schools with Virtual Math Festivals and other online interactive math activities this fall and beyond.

More information is available at our K-12 programs website, [mathcommunities.org.](mathcommunities.org) ■

– Spencer Bowen and Brianna Donaldson







Left: Festival attendees choose from a variety of interactive online activities, including Witches' Cauldron. Center: Students move from table to table to collaborate with each other on different activities. Right: One of the most popular activities explores some of the mathematics behind gerrymandering.

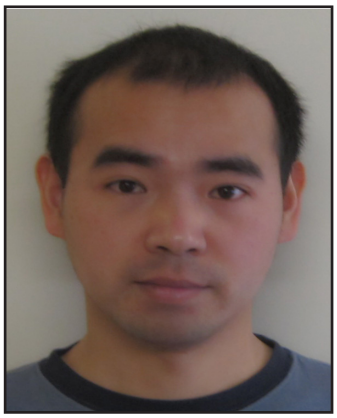
Alexanderson Award
Third Award Announced

Laura DeMarco, Holly Krieger, and Hexi Ye are the recipients of the 2020 Alexanderson Award for their paper, "Uniform Manin-Mumford for a family of genus 2 curves," which was published this year in the Annals of Mathematics. The paper grew out of the AIM SQuaRE, Dynamical Andre-Oort Questions.

In this paper, they study the geometry of surfaces and how each sits inside a 4-dimensional torus, called its Jacobian. There is a large set of special points in this Jacobian, its "torsion" points; but in the early 1980s, Raynaud proved that the surface will intersect only finitely many of these points. This finiteness statement was called the Manin-Mumford conjecture. Soon after, Mazur posed an important question about these surfaces, asking if we can bound the number of the special points on the surface only in terms of its genus (the topology of the surface), or if there is additional geometric information we need to know to control the size of this intersection.

Although not obviously related to number theory, much progress on questions of this sort has been made over the years with tools from algebra and arithmetic geometry. But Mazur's question about a uniform bound remained elusive.

In this paper, DeMarco, Krieger, and Ye also employ arithmetic tools, but their novel insight was to use ideas from dynamical systems to finally provide a uniform bound on the number of torsion points in a special setting. They study a family of surfaces in genus 2 that map to pairs of elliptic curves (surfaces of genus 1), and they give a positive answer to Mazur's question for this family. The proofs employ a quantitative version of arithmetic equidistribution to relate the heights (i.e., the arithmetic complexity) of the surfaces to the number of torsion points.



From top: Laura DeMarco, Holly Krieger, and Hexi Ye

Due to the pandemic there will not be a 2020 Alexanderson Award Ceremony and Lecture, but we hope to have a celebration in the future.

Last year's award was received by Paul Bruillard, Siu-Hung Ng, Eric C. Rowell, and Zhenghan Wang for their paper, "Rank-finiteness for modular categories," published in the Journal of the American Mathematics Society in 2016. The award was presented at the Alexanderson Award Ceremony and Lecture on the evening of October 4, 2019, in the Recital Hall of Santa Clara University. The lecture was given by Jordan Ellenberg, the engaging author of the book, *How Not to Be Wrong*. The lecture focused on how mathematics uses building blocks of simpler things to understand more complicated objects, much the way we do in chemistry. A video of the talk is available on AIM'S website, **aimath.org**. ■

– Estelle Basor

About Gerald Alexanderson

Gerald Alexanderson was a member of the Santa Clara University faculty beginning in 1958 until his retirement in 2018. During that time, he was Chair of the Mathematics department for 35 years and a member of the Faculty Senate Council. For thirty eight years he held the endowed Valeriote Professorship of Science Chair. He is author of more than a dozen books, including textbooks in abstract algebra, and discrete and combinatorial mathematics. Alexanderson was the first recipient of Santa Clara University's Bayma Award for Scholarship, and he received the Special Appreciation Award from the Dean of Arts and Sciences as well as the Special Recognition Award for Teaching, Research, and Service from the President of the University.

Alexanderson's influence has extended to the national level, where he has played a leading and lasting role in the Mathematical Association of America (MAA). His contributions to the MAA have spanned more than 50 committees and 24 years on the Board of Governors, encompassing Secretary, Vice-President, and President of the Association and Editor of *Mathematics Magazine*. Results of this work include the remodeling of the MAA Carriage House in Washington, D.C., into its Mathematical Sciences Conference Center. In this time, Jerry served on the Science Policy Committee of the American Mathematical Society (AMS) and was a consultant to the Editorial Board for the Bulletin of the AMS. In testament to his expansive record, Alexanderson received the MAA's most prestigious award for distinguished service to Mathematics, the Yueh-Gin Gung and Dr. Charles Y. Hu Award.

REUF

Growth and Evolution

We are pleased to announce that the NSF has awarded funding for four additional Research Experiences for Undergraduate Faculty (REUF) week-long workshops and subsequent collaboration meetings. The workshops will be held at AIM in 2021 and 2023, and at the Institute for Computational and Experimental Mathematics (ICERM) in 2022 and 2024.

The REUF program aims to enhance the ability of faculty at undergraduate colleges and universities to engage their students in research. It also serves as a research renewal/support program for many faculty participants, engaging them in long-term research collaborations and enabling them to develop expertise in new research areas that have problems accessible to undergraduates. Due to the high demand, the upcoming workshops will expand from 20 participants in four teams to 25 participants in five teams in each workshop.

REUF also continues to evolve in other ways. As we all adjust to the need for remote work in the current crisis, we are hearing from potential participants who would value the option to participate in REUF remotely, and this is being explored. Also under discussion are more options for methods to continue collaborations formed at the workshops. ■

– Leslie Hogben

Hidden Gems

Exploring the Rare Book Library

Upon AIM's move from Palo Alto to San Jose in 2014, we inaugurated workshop tours of the rare book library, a collection of mathematical books and reprints from the 15th through 20th centuries.

These tours follow a regular procedure, beginning with reading up on the week's workshop, selecting relevant material, and mounting displays. Tours for workshops whose focus involves some aspect of calculus, say, or probability, prove fairly routine to put together. I can easily fill three cases with books and offprints as the library is rich in these fields, encompassing both major and minor works. Many workshops however require more thought and a deeper dive into the collection, occasionally supplemented by items from the extensive AIM reprint library. The common denominator among all displays however is a mix of big and small, the well-known with the unfamiliar.

During the tour I generally give a brief history of the library's origin in 1990, some discussion of its particular strengths (number theory, non-Euclidean geometry, logic, to mention a few) and, finally, a close look at the works on display. Depending on the questions I'm asked, my remarks can touch on typography, bindings, printing history, mathematical history, the rare book trade and prices, auctions, and, always, the practice of acquiring rare mathematics. The audience is invariably informed and enthusiastic.

In recent years I've been asked to name my favorite item in the collection. My initial response alternated between "the last book we bought" and "the next book I'm looking for." Although admittedly a bit flippant, those answers are valid: librarians are acquisitive. It's part of the job description!

As I thought about it, I realized that my favorite piece is the elusive, little-known (or unappreciated), often exceedingly scarce work that is or seems collateral to the main publication(s). These favorites are almost all physically small (8vo or 12mo) and/or slight (a few pages in length). They represent the sort of artifact that is easily discarded over the centuries, due perhaps to its modest physical character, or perhaps because its importance was overlooked at the time of writing, or because it was printed in a tiny edition – there are any number of reasons. To be sure, there are many slight publications that were widely circulated and influential upon arrival – e.g., Huygens' brief *De Ratiociniis in Ludo Aleae* appended to Van Schooten's *Exercitationum* of 1657; Riemann's paper on the zeta function, *Ueber die Anzahl der Primzahlen* (1859); Frege's *Begriffschrift* (1879). We have many such examples in collection and they are among our most prized pieces. However, I am particularly devoted to that underappreciated (occasionally unpublished) work whose significance emerges only over time.

Please see back cover for several illustrations. ■

– Ellen Heffelfinger

THANK YOU

AIM gratefully acknowledges the following donors for their generous contributions of books, reprints, journals, and archives to the AIM library between September 2019 and July 2020:

Roger Alperin
Michael Artin
John Barrientos
Mary Jennings (collection of Donald Sarason)
Gethin Rees (collection of Elmer Rees)
Carol P. Tate (collection of John Tate)

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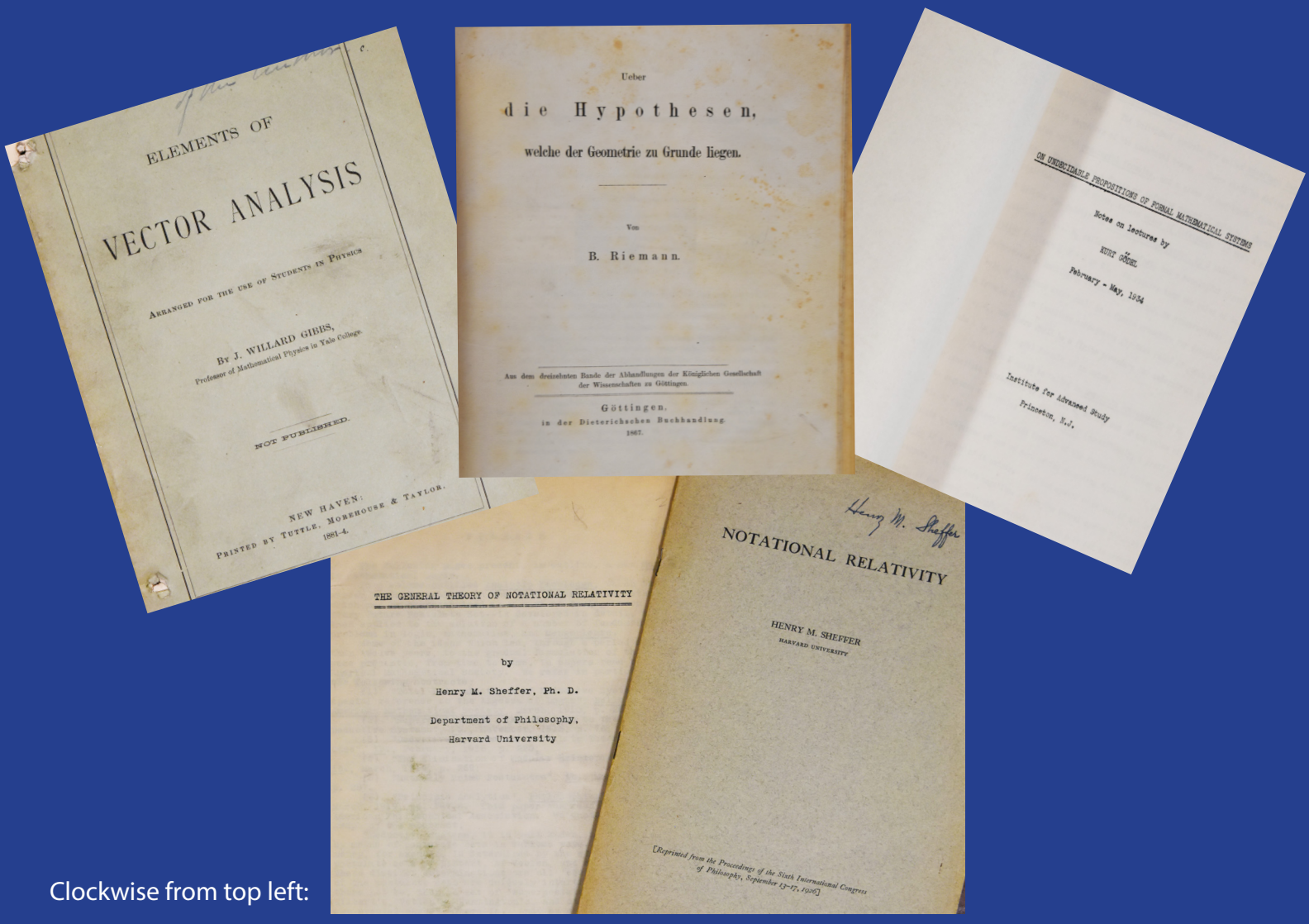
From Our Collections



Clockwise from top left:

Gibbs' pamphlet was printed for private distribution only to the students in his classes and to select correspondents. Posthumous publication of Riemann's 1854 paper on the foundations of geometry, including the introduction of Riemannian spaces. Alonzo Church's copy of mimeographed notes of lectures given by Kurt Gödel at Princeton in 1934. In these lectures Gödel introduced the notion of general recursiveness. Privately circulated mimeographed typescript of Henry Sheffer's seminal work; it remained unpublished other than a brief article in 1927.