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Count Me In

Community and Belonging in Mathematics

Edited by
Della Dumbaugh
and
Deanna Haunsperger

AMS American Mathematical Society

MAA Mathematical Association of America

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Introduction
The Power of Community

In the spring of 2020, with nearly every high school and collegiate graduation cancelled, former President Barack Obama delivered a universal commencement address. After some introductory remarks, he outlined three pieces of advice.

(1) Start. Start with an idea to make the world better;

(2) Do what is right; and

(3) Build a community. "No one does big things by themselves. Be alive to one another's struggles...set the world on a different path."

Build. A. Community. Without any coaching from us, Obama captured the essence of this volume with these three words. As Obama noted, however, this suggestion is inextricably linked to the ideas of "beginning" and "aiming for goodness." Although Obama designed his remarks for a general audience, he actually described the process of creating a *mathematical* community. This book offers insight not only into this process but also into the rich results that come from this investment. It is our hope that this combination of "how to" and "reward" will encourage you to join and sustain a community that already exists or start your own where you recognize a need. Either way, you will advance yourself and your colleagues.

This text introduces readers to 26 communities in mathematics. The book is organized into two sections, "Communities for Undergraduates and Secondary School Math Students" and "Communities for Graduate Students and Professional Mathematicians." This bipartite arrangement testifies to the importance of a community both when we begin our mathematical journeys and while we sustain them. These chapters tell a story, individually and collectively. The book itself represents a community of authors who each write in their own voice, from undergraduates to seasoned professionals. They stretch out to and include all corners and crevices of the mathematical community. They celebrate how diversity *and* sameness bind colleagues together. The former fosters friendship, the latter builds confidence, and vice-versa. They offer outcomes measured by mathematical results and mathematical research collaborations. They show how geography, gender, or graph theory can create spaces for people to come together. They highlight the value of relationships with peers and colleagues at various stages of their careers. They underscore the power of supporting others.

Prepare2Nspire, a near-peer tutoring program in Minnesota born out of state-mandated changes for algebra education, captures this support in their observation that "[t]here is something powerful about walking into a room filled with people who look like you doing mathematics. It builds you up in a way that makes you feel accepted, and implicitly makes you feel like you are a valuable member of that community." These thoughts actually resonate throughout the volume in communities as seemingly disparate as the Women and Mathematics Program at the Institute for Advanced Study in Princeton to summer programs in combinatorics for undergraduates in Colombia. From this we learn that although the chapters in this volume describe different places and people, they combine to reveal common ideas that point to the powerful shared experience of mathematicians who find meaning and strength in a community.

The collective insights of these chapters also highlight shared strategies for success in creating, building, and sustaining communities. Although many communities begin by recognizing a need, that is generally a single first step. From there, colleagues build a scaffolding that centers the type or scope of mathematics within the group, establishes and focuses on inclusion, rotates leadership, leverages the energy of participants to share their expertise in the group and beyond, maintains a vision for the program, and obtains funding and other forms of support. This framework provides the foundation for the community. The ongoing solid structure relies on the continued combination of these initiatives with necessary adjustments gleaned from feedback, assessment, and broader changes in institutions and organizations. By way of an example, as the Mathematical Sciences Research Institute (MSRI) began to increasingly focus on diversity, inclusivity, and equity as an institution, they realized their entire staff—"from the building manager to the Trustees"—needed to embrace and live this mission. The culture of their programs changed when everyone from the custodial colleague placing the chalk on the chalk tray to the administrative colleague discussing mathematics with a Fields Medalist visitor adopted this spirit of inclusivity. And the community is all the richer for it.

Taken together, these chapters provide a guide—rather than a template—for building a mathematical community. They show that although this process is not "one size fits all," there are some consistent strategies for success. Not surprisingly, for example, leadership emerges as a critical component in building community. In particular, many communities featured in this volume make an intentional effort to distribute leadership among members, including initiatives that cultivate these skills in younger members of the group. Many of these communities are unafraid to look themselves in the (proverbial) eye. That is, they benefit from ongoing and real-time evaluation of their programs. They assess themselves, they listen to the assessments of their participants, and they reflect on what they learn. These communities also consider the humanity of the members engaged in the pursuit of mathematics. This aspect of community building and growing may involve providing food for high school students in the afternoon or arranging childcare for parent-researchers to dedicate a week to their scholarship. These groups remind us that mathematicians are people who do math. And people are humans. And humans thrive when they belong to a community.

This idea of "community" is not new. When William Aspray wrote his important work on the "Emergence of Princeton as a World Center for Mathematical Research, 1896–1939," he could have focused exclusively on the seminal mathematical results Princeton

faculty developed during this time period.[1] But he didn't. Instead, he highlighted that "[s]everal principles were consistently applied by [Henry Burchard] Fine, [Oswald] Veblen, and others over the first forty years of the century to build excellence in the department and later in the institute." These "principles" included not only an emphasis on outstanding mathematical research, but also on an intentional effort to "build a community of mathematical researchers." The leaders at Princeton recognized that "seasoned faculty and young aspiring mathematicians could exchange ideas" and they made a purposeful decision to adopt an international perspective and build up a research community through young mathematical talent [Aspray, 358–359]. They understood the inextricable link between mathematics and community. That is, on a fundamental level, your key mathematical result is only influential if the community recognizes its worth and power. And that community is sustained, in part, when you pass along your mathematics to the next generation.

That community is built and sustained in other ways and for other reasons.

The same Veblen—who played a critical role in the Princeton initiative in the early 1920s and subsequently served as the first director of the Institute for Advanced Study—was invited, at the age of seventy, to give the opening address at the 1950 International Congress of Mathematicians. At that point in his life, he had a rich collection of moments and experiences in mathematics to draw from for his topic. His choice for this celebrated occasion? Belonging. Yes, belonging.

"Every human being feels the need of belonging to some sort of a group of people with whom he has common interests," Veblen told the crowd of colleagues. "Otherwise he becomes lonely, irresolute, and ineffective. The more one is a mathematician the more one tends to be unfit or unwilling to play a part in normal social groups. In most cases that I have observed, this is a necessary, though definitely not a sufficient, condition for doing mathematics. But it has made it necessary for mathematicians to group themselves together as mathematicians. The resultant organizations of various kinds have accomplished many important things known to us all. Of these accomplishments I am sure that the most important is the maintenance of a set of standards and traditions which enable us to preserve that coherent and growing something which we call Mathematics."[2]

Veblen was right. He was also ahead of his time. It would be decades before researchers would confirm the essence of his message. Then and now, community, and, specifically, belonging to a mathematics community, matters. But what does it mean to belong? Belonging is the extent to which an individual feels accepted, valued, and legitimate within the community. For mathematicians, this means we have a mathematical home where we feel welcome. In this comfortable space, we can be at our best. Psychologists James Coan, Hillary Schaefer, and Richard Davidson have shown that when friends or loved ones are nearby, for example, our bodies react less to stress.[3] Being a part of a friendly/

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[1] Aspray, William. 1988. The Emergence of Princeton as a World Center for Mathematical Research, 1896–1939. In Aspray. W. and Kitcher, P. (eds)., *History and Philosophy of Modern Mathematics*. Minneapolis: University of Minnesota Press, pp. 344–364.

[2] Veblen, O. (1950). Opening Address of Professor Oswald Veblen. Presented at the 1950 International Congress of Mathematics, Cambridge, MA. August 30.

[3] Coan, James, Schaefer, Hillary, Davidson, Richard. 2007. Lending a Hand: Social Regulation of the Neural Response to Threat. *Psychological Science*. 17 (12): 1032–1039.

non-threatening community is healthier for our bodies and allows our brains to function at full capacity. Mathematicians (and others!) need their brains at their best.

Gregory Walton, Geoffrey Cohen, David Cwir, and Steven Spencer have demonstrated that a sense of belonging can affect IQ performance, motivation, and persistence, even on impossible tasks.[4] And what can feel more impossible at times than one's mathematical research? In other words, without feeling like you belong to a community, you are less likely to stay the course when obstacles arise, less likely to find the inner strength to continue, and less likely to make outstanding achievements. Framing these outcomes positively, when you feel like you belong to a community—that is, you feel accepted, valued, and legitimate—you are more likely to stay focused, remain resilient, and perform at the highest level.

So whether you are giving thought to starting a group to promote a sense of belonging, joining one already in existence, or encouraging a colleague to participate in the broader mathematical community, this book will meet you where you are—and move you beyond. The book is designed for you to read most chapters in less than half an hour and discover a plethora of ideas—or just one—to move you towards a sense of belonging somewhere in the exciting discipline of mathematics.

This collection of chapters, of roadmaps for finding belonging, show how colleagues come together through a shared connection. These communities promote a larger vision for each individual and a richer purpose for the group as a whole. They show communities as supportive structures that join together to create the broader mathematical community. They reveal the power of pursuing and doing mathematics as part of a community.

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August, 2020

[4] Walton, G., Cohen, G., Cwir, D., and Spencer, S. 2012 "Mere Belonging: The Power of Social Connections." *Journal of Personality and Social Psychology*. 102 (3): 513–532.

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It takes a community to write a book about community.

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Finally, and perhaps most importantly, we offer our heartfelt thanks to the many people who advance mathematics individually and collectively on a daily basis, especially those who believe in students and colleagues long before they believe in themselves. This single act often forms the foundation for success for an individual who later contributes to and benefits from the broader community.

I

Communities for Undergraduate and Secondary-School Mathematics Students

1

Building Community in the Classroom

Erica Winterer

At twenty-two years old, I started my teaching career in a New Orleans high school. My oldest student was twenty-one and on my fifth day, a sophomore named Malaysia asked me if I was trying to be Hilary Swank (referring to her *Freedom Writers* portrayal of Erin Gruwell, the American teacher known for her unique teaching method used to inspire at-risk youth to further their education). She wasn't wrong. Even though I knew next to nothing about my students' community, I thought I would make an excellent teacher because I understood the content. Misguided and over-confident, I muddled through my first two years of teaching. I wasn't the worst, but I definitely wasn't the best. My students undoubtedly deserved better.

After two years of teaching, I could finally manage the paperwork, mostly manage upwards of thirty teenagers, and keep the rats from eating the corners off the reward Starbursts; however, I was still blindly flailing through attempts to build "classroom culture." Always a pillar of professional development, but never clearly defined, classroom culture was a slippery, murky creature I would rather avoid than chase after. Every example offered to me seemed like some wizard teacher with a unicorn personality was able to effortlessly inspire groups of teenagers with their nebulous teacher moves. All the magic seemed to hinge on these teachers' personalities which was far removed from mine. I am not a particularly funny or gregarious person. I prefer small groups of people, have very few close friends, and avoid attention. The best choice I made was to stop imitating these examples.

Students valued my authenticity more than my ability to entertain them. We built community by building trust. I demonstrated care for students through high expectations, highly organized lesson plans, and praise for their individual progress. My investment in students' success and our shared responsibility for the course combined to foster and grow a community. I will never be Jaime Escalante (the Bolivian-American educator portrayed in the 1988 film *Stand and Deliver*) and that is fine. We can still build community without magic.

I had to repeat this mantra the first time I saw my graduate advisor, Uri Treisman, teach his freshman calculus class. He is one of those wizard instructors, seamlessly integrating expertise from mathematics and psychology to forge a transformative experience for students. A highly respected figure in the community of mathematics, he has long been committed to equity-minded teaching, starting with his work at UC Berkeley and the creation of the Emerging Scholars Program [6]. I spent the first two years as his TA just trying to catalogue (and organize) all the moving pieces of the course. As I read more of the literature, I realized the magic of the course was a combination of expert knowledge, intentionality, and many iterations. Every decision that is made, no matter how small, is considered and informed by research and our collective teaching experience. How should we frame the exam results? If we say XYZ, what will students hear? What do they need in this specific moment? Which students need more challenge? Which ones need more support? Do they all need a win to lift morale? Everything matters. I am now in my fifth year of my doctoral program and have graduated to co-teacher of this freshman calculus course. The course has extra resources (e.g., undergraduate TAs, me as a co-teacher) but we consider it more of a laboratory than a replicable model.

We work with leading psychologists, including David Yeager, to design classroom environments that promote positive learning mindsets. Specifically, we carefully conceive and employ structures, routines, and rituals we think will positively influence students' growth mindset, purpose, and belonging. These structures, routines, and rituals in combination with personal connection and shared responsibility help to create a sense of community in the course. In this chapter, I will share some specific examples of how we try to build connections with and between students, in the hope that they might be helpful in building community within your own course. These examples were chosen based on student interviews I conducted two years after a section of the course ended. They were the course components which most students remembered and which seemed to have a lasting impact. While each course component is based on a combination of mathematics, education, and psychological literature, the intention of this chapter is to simply share strategies we employ and student reflections. For that reason, I do not include a detailed discussion of the academic literature [2, 3, 7, 8, 10].

Community is sustained through the connections between its members. Without these connections, intended messages can be lost, misinterpreted, or ignored. We try to build an environment that fosters connection not only between students and the instructional team but between students themselves. Courses, especially large lectures, can often feel impersonal and students wear their anonymity like camouflage. Instructors are often happy to play along. It is difficult to feel a sense of responsibility to a student you know nothing about, and teaching is one of many demands on our time. We must work purposefully over the course of the semester to disrupt these social norms and practices that isolate students from their professors and each other.

Welcome students

This starts on day one by welcoming students to the course. The purpose of day one is to signal to students that we want to know them, induct them into the mathematics community, and set the expectation that the course is difficult by design. We start by trying to

Photo credit: Lana Fukasawa/Department of Mathematics, UC Berkeley.

Uri Treisman in a Math Workshop at UC Berkeley, Fall 1978.

learn our students' names before the first day of class. With class sizes of about 130, this means we quiz ourselves with flashcards made from their ID photos of questionable quality. Clearly, we never get all their names correct that day or even within the first two weeks; we do get enough names right to shock students and let them know we see them. Many students have reported that just using their names made them "feel more comfortable and like the class was less daunting." They have also said that just "calling someone by their name draws you to that person and lets them know they see you as a person—not just a student." Learning students' names is time consuming on the front end, but the return on that investment runs the course of the semester.

We also use the first day to establish common ground in the content. We display their math genealogy, introduce them to their ancestors, and tell them we are now and forever their teachers. We frame the content of the course as their legacy, i.e. something that they are entitled to and do not have to earn. We get mixed reactions—

> *I guess he would list a bunch of old mathematicians and say they were our ancestors? At first, I was like what is this guy talking about? Afterwards, I was like OK, he's just saying if they were able to do it, we should be able to do it.*

> *I do remember feeling like it made me, like a part of a group. Like a part of a very smart group who knew very smart things, and I could do it. Ya know? I'm up there with the, uh, triangle guys.*

> *He made us feel like math was a part of us. Which was really nice because I know for a lot of people if they find a topic really difficult, they tend to give up on it and say this is*

not for me, like I'm not meant to be doing this. But, even though it was a simple thing of him being like, look at how all these people are related, it made us feel like—oh, we can actually do this. Or like, we actually have the ability to do this, like, inside of us. It's not just something that I just wasn't born to do.

I kind of questioned the credibility, if it was true or not. But I liked the idea of it. Um, it was just showing that we're somebody in this long lineage of people—at least instilling in us that you're somebody. You're not just here to take a course credit and get out of my class. Like, you're going to be here, and you're going to be my student forever kind of thing rather than you're just going to be here and you're going to move on.

Conducting these interviews two years later, I realized that I underestimated the impact of the genealogy ritual. This simple ritual resonated with students in a way I did not expect—and in some cases reinforced their sense of capability and membership in the mathematics community. Over the course of the semester, Uri references these ancestors to communicate that while we expect students to learn the material quickly, these ideas are complicated and famous mathematicians struggled with them before us. He will explicitly message that there are specific tricks that his advisor passed on to him and he will pass to students. These tricks are not things that they should know in advance or be able to derive through their knowledge or common sense. We want to prevent students from questioning their intelligence if they do not immediately understand an idea. We cannot expect students to feel like valued members of a community if they doubt their own capability and contributions.

Toward this end we do our best to encourage students to attribute any difficulty or struggle in the course to our intended design and not personal deficiencies. We hope that these first impressions help to sow seeds of trust, but it is tentative; they still don't know us.

Make the first move

As instructors we need to demonstrate that we care about students and that this is not just some formal, impersonal classroom. Social norms establish distance between professors and students. Often there is an unwritten agreement that they don't bother us and we don't bother them. We both show up and play our respective roles while maintaining a comfortable distance. Intentional work is required to disrupt these social norms that isolate students from their instructors and each other. These are norms in our society which make real teaching difficult. Unless we disequilibrate them, and do so with integrity, real teaching cannot occur. We need to explicitly tell students that we want to know them, and we expect them to know us, while creating conditions for new, more productive norms to evolve.

We know relationships with faculty are important to students and research shows that these connections positively influence students' academic outcomes. However, students intimidated by professors are likely to avoid faculty and instead seek help from their peers or struggle in isolation. For these students, professors' expert knowledge paired with a serious or hyper-professional demeanor makes faculty seem unapproachable. These students miss out on opportunities when they don't make connections with professors, and we miss the chance to know our students, to see first-hand what sense students made of a lesson

or lesson-slice, or at the macro-level, how the course is shaping students' interests and aspirations.

This disequilibration starts with us making the first move. There are simple ways we can initiate conversations and connect with students to avoid these missed opportunities. For example, students describe instructors who just ask them, "how are you," and genuinely listen to their response as "caring." Taking the time to ask students about their degree plans and to encourage them can make students feel validated in their academic pursuits, like their potential is recognized. As little as one conversation with a professor can dampen students' doubts and reaffirm their belief that they can be successful in college.

To quote a former student, "It's one thing to say you want to get to know your students, it's another thing to actually do something about it." We do a few things in class that signal to students that we want to know them and care about their progress:

- We make small talk before and after class with individual students. Ask them simple questions like "how are your other classes going?," "how is your day going?," etc.
- We schedule test reviews outside of regular lectures, to interact with students in a more informal environment.
- We learn and use students' names in lectures and discussion sessions (not always perfectly, but they appreciate that we try!).
- We announce to students that everyone is expected to attend at least one office hour.

Every professor is required to schedule office hours; not every professor actually wants students to show up. If we want students to come to office hours or to reach out for help, we need to signal that we actually want them there, that we are invested in their progress. To signal that we actually want students to come to office hours, we notice who hasn't shown up and email those students. Now, I don't think it's necessary to send office hour invites to every student who hasn't shown up, but I do track who has attended. The idea is just to let students know you want to see them. If we email a few individual students, word will get out that we meant it when we said we want to see everyone in office hours. It is our responsibility to make the first move because students will always follow our lead.

Even two years later, students remembered the efforts to engage with them and open lines of communication:

> *He made the effort to come up to me, ya know, a few times … and say, 'Sophia!', because obviously he knows everyone's name, and like kind of just catch up … He a lot of the time would make the first move. Which is not really a thing you see with professors happen at all … In a lot of other classes, professors just are not going to speak until they are spoken to. Which is, like, a really common thing. But I think Professor Treisman, like, he didn't care. He was like, I'm going to introduce myself to everybody.*

> *… I remember now, even in lecture, he would make a really big deal about like, you coming to his office hours. He would say, 'I still haven't seen so and so people' or … he would really emphasize wanting every single person to go to his office hours or make an appointment so he could get to know them.*

> *At the end of class he would randomly stand in front of the classroom and just like ya know, that's where he was before and as people were leaving he would just maybe just*

wave or smile or be like hey how are you doing, how's this and that or something we previously talked about.

I think Professor Treisman also made a big deal in wanting to know about the student also. He would, ya know, like, ask you 'How are your classes going? What classes do you want to take?" Or he would say, 'What are you interested in?' … 'Oh you're physics? Are you going to do FRI [freshman research initiative]?' Ya know, he kind of had an idea of how the system works here and kind of would like, ask us questions seeing where we are in that system, like what are we doing that is right. And we would just talk about what's going on, like, how was your morning going, or he's going to a flight directly after class and he has a suitcase with him. Yeah, it didn't have to be complicated with him I think.

Let students know you

Even though students appreciated these efforts, it is unfair for them to be the only ones sharing about themselves. We try to share personal anecdotes, stories about our work, interests, and hobbies to disrupt the power dynamic and make students feel more comfortable. As instructors, we may not perceive ourselves as intimidating or unapproachable. However, knowing that students are often intimidated, we must make a conscious effort to build relationships. An important part of relationship-building is letting students know you. Having informal, balanced, personal interactions with students can have a significant influence on the classroom dynamic and student performance. Although it takes work, research has shown that increased rapport with students impacts participation as well as effective and cognitive learning. It's easier to approach someone you feel like you know personally, and students rate approachable professors as more effective overall.

As a teacher of undergraduate students, I recognize that many students walk into class already intimidated by professors, determined to never show confusion. Students look up at professors and see someone who has climbed above them, separate and fundamentally different from themselves. This dynamic simply exists within the current system, and we anticipate it when the semester begins. To make students more comfortable, we try to chip away at this "Us vs. Them" power structure. We humanize ourselves by sharing information about our lives and work. It could be anything that is honest and authentic to ourselves. We might tell students about: a conference that we went to, a paper we read, some of our research, a hobby, a short anecdote, our recent travels.

Sharing personal stories or interests helps to close the distance between us and our students. We recognize that students need to know a little bit about us before they can be vulnerable with their confusion. We try to communicate to students that it is not innate intelligence that separates us, but education, training, and practice—experiences that they can also collect over time. Also, who doesn't like to just know a little something about the people they work with?

In interviews, students emphasized how professors sharing information about themselves humanized them and made the class feel more connected:

He also shared his own personal story a lot. Which, um, was pretty good, because that really humanized him 'cause he wasn't just some big authority on campus in calculus,

he was also like, he's from the Bronx right? [laughter] Yeah, also a guy from the Bronx, so that was pretty cool.

There was, like, one story that I always remember he told … that he was a fan of the baseball team from Brooklyn and they moved from Brooklyn to Los Angeles. Um, and he told the story and it was very funny but, then he just went right onto teaching. But, I think that kind of thing makes a professor a lot less intimidating. You can just tell a story like that, and it's like, you're not forcing it, it's just like … somehow it came up. I don't know how. And you distill it, and then you know, you're just seeing that human aspect.

A lot of the times you don't really know a lot about a professor besides, like, Rate My Professor, ya know? But it's nice to get, like, the story behind the person 'cause nowadays it's more like … in the students at UT it's kinda like us versus them … where students are tryin' to pass this class, get through it somehow, but more than that it's like … I feel like there's a lot behind professors … there's so many weird amazing things I find out about my professors, even the ones I don't like, and it's like I never learned to appreciate it because I was so stressed out from the class … I guess it's nice to know, like, I dunno, there's much more to a professor.

Help students know each other

It's not only important for us to forge connections with our students, but we should also foster connections between students themselves. My own greatest fear in undergrad was asking a stranger a question. I was sure the other students in engineering knew everything and asking any questions would just confirm that I was the only one confused. If I had a question, I always ran it by a friend I trusted. I needed to know that my question was reasonable and would not make me look ridiculous. If I asked a silly question, I knew they wouldn't assume I was a silly person.

I conveniently forgot this experience in my first few years of teaching. Despite explaining group work procedures with precision, offering explicit directions and exemplar groups, students rarely took risks or interacted in the ways I envisioned. In fact, without intervention, students often spend an entire semester sitting next to the same people without knowing their names. When working with others, students usually subscribe to the norms of interaction, are nervous to ask for help, and are intimidated by the fear of looking unintelligent. Research shows group work and collaboration benefit learning and future careers; however, a quick google search reveals people are not naturally good at working together. Putting people in the same space or telling them to talk does not result in higher productivity; the collaboration must be strategic. So, how do we connect students and effectively coach them to work together?

Watching Uri teach, I realized students only fully engage with the content when they feel safe presenting their work and ideas. Since it is easier to feel comfortable working with people you know, Uri starts class by encouraging students to know each other's names. It seems overly simplistic. However, students have told us that just knowing another student's name makes it easier to ask them a question or to collaborate on an answer. I was chatting with a student about this and he said, "Yeah, what am I going to do if I don't know their name? Say yeah, hey you, can you help me with this?"

Beyond learning names, we encourage students to work together throughout the semester, not just on the first day of class. For example, we:

- Make time for students to meet each other/exchange contact information on the first day of class.
- Offer extra credit for the first homework assignment if it is completed in a study group. (Students email us the members of their group, where they met, length of the session, brief description of how it went, and a hook 'em horns selfie of the group.)
- Assign group problems during lecture and instruct groups to spend the first minute on introductions.
- Set the expectation that students should know each other and cold-call students at the beginning of class, asking them to name three people around them.
- Remind students to study in groups throughout the semester and give a quick mid-semester google survey to make sure everyone has a study group. We might try to connect isolated students to a few different groups to give them options.

This intentional connecting not only builds community but supports students' academic success. It is something I wish my courses had emphasized when I was a student. Listening to our students reflect on how they remembered routines designed to get them to know each other, I realized how easy it would be to underestimate the impact of this simple act. They really valued the formal time during lecture dedicated to helping students connect and noted how it was not something they experienced in most undergraduate courses.

> *We go to panels and the students are always like, 'Yeah like make sure you're like talking to the people around you in class. Ya know it's super important throughout your college experience. Ya know study groups …' I feel like even before I went to college people always said that. But I think that Dr. Treisman recognized that that's not something people are just going to do. Ya know, like no matter how many times you hear it—oh you should really talk to the people around you and get to know them—that students won't do it.*

> *Starting the first day of class he would call on you and be like, 'hey, who are the people that are around you?' And that kind of fostered more of a community environment than any other classes that I've had before. Calculus is really difficult and if you don't have that kind of support system, you're not used to meeting your classmates and forming study groups, it's really hard to succeed, especially as a freshman.*

> *We had that thing where we would tell each other our names, or he'd ask us who was sitting next to us. That. I loved that … it was just the best … I felt comfortable. And I think when you feel comfortable, you feel like you can ask for help.*

> *In the very beginning it was like, why do you want me to know the person's name next to me? Like, he's just going to sit next to me every day in class, and that's how it is in other classes. It's like those people sit next to you and you never really acknowledge them. And so, in the beginning it was like why are you making me acknowledge this person next to me? And then it became evident, why he was having us work in groups. I think the homework sessions made me realize the importance of that.*

Extra credit selfie of a study group.

I could see how some people would get stressed out and be like, man, why do I have to learn these people's names? But, I think it's kind of an important thing, 'cause especially so in college you get really disconnected. And especially at a school like UT, there's so many students here, like thousands, but you can feel like isolated, um, really easily. So, I think even just knowing someone's name can open up … like, it's more important than just inside the class, maybe outside the class even?

Honestly, I loved that you were forced to talk, not forced, but it was like, he encouraged us to talk to the people around us and getting to know others' names and getting to know people we wouldn't normally talk to. Um, it really helped because in a class like that one, where the content is really hard and it's like you have to spend a lot of time studying and stuff, knowing that there was other people around you and putting a name to their face, and understanding that they were going through the same thing, made it a lot easier for you to actually reach out to people being like 'hey, I don't understand this can you help me?' And then as well, like, it being … was my first semester, being encouraged to talk to people around me really helped me make friends and I still talk to a lot of people from the class. And, although none of us are in the same class [now] it's just … since we were given the opportunity to get to know each other we kind of bonded over the class itself and then it grew into a better friendship which was really nice and I really liked that a lot.

Stereotype threat, belonging, and the importance of community

Students are usually aware of negative stereotypes related to their identity and their awareness often amplifies as they age. Stereotype threat refers to the psychological impact

of stereotypes that allege inferiority of marginalized groups in a certain domain [1, 5]. In a situation where a student assesses their group's stereotype as relevant, a student may feel an extra psychological burden relative to their peers who are not in the same group. This activation of stereotype threat is dangerous as it can lead to disidentification with academic subjects and undermine emotions that intrinsically motivate students to learn. For example, Catherine Good demonstrated that stereotype threat can suppress the test performance of even the most qualified women in college-level mathematics [4].

Evidence points to the potential of stereotype threat to interfere with a student's problem-solving capacity in our classrooms. We should acknowledge this and work to create a classroom environment that mitigates the effects of stereotype threat by promoting feelings of belonging. Gregory Walton, Geoffrey Cohen, and David Yeager, among others, have produced extensive work around this topic [7, 9]. The previously-described strategies to facilitate connections with students should help with this but we should also encourage students to interpret threats to their belonging as a common experience that is shared, normalized, and transient among the undergraduate population. To create this effect, we explicitly message to students that the course is difficult by design and that students struggle through it every year. We also try to share our own stories of academic struggle and we bring in a panel of past students to discuss how they struggled, persisted, and then excelled on the final exam. Again, our goal is that students attribute experienced struggle to the design of the course and consider it a normal experience rather than any perceived deficiency on their end.

Our students really appreciate these shared stories of struggle, both from me and Uri, and our former students. In the interviews I conducted, they expressed how these examples gave them perspective and normalized the struggle they were experiencing. Here are a few comments from those interviews:

> *I remember my freshman year, you were saying, back when you were doing engineering, you had people tell you at one point that you shouldn't do engineering anymore. And, I, recently because of health issues had my GPA drop and last semester my advisors were like you should just withdraw from the semester and do it over again. And I was like, no, I really think that I can still do this—it doesn't matter my GPA dropped a bit because of health things … it's still possible. So, thank you for telling me that.*

> *I remember one day we had a review session and he invited three people and one of them told her story about she herself was coming from a high school with less than enough calculus experience and she was scared and wasn't doing as well as she wanted. And then she's up here, success story, like, she's doing great. It provided a sort of encouragement … he's not just telling us that we can be good at these things … he's bringing an example for us … the effort just made me feel like it was worth working hard for.*

> *When you're struggling it feels like you're just going to be there forever. Whenever he had his students come and talk to us, I was like, OK, there's an end to this madness. Everything's going to be all right. They did fine. Somehow, one way or another, we're all going to be fine. I guess, it made me not lose hope because I feel like … struggling in math class was like losing hope and gaining hope, losing hope and gaining hope.*

Make it your own

While the strategies outlined in this chapter have been effective for us, they make up only a small slice of our course. These examples were offered as potential ways to begin building community, not to imply this is all that is needed or the only way to do it. There are essential elements woven into the fabric of our course: established trust, shared responsibility, expert content, and pedagogical knowledge, etc. I suspect the described strategies would not have the same effect if they were implemented in isolation or without a certain level of established trust between instructors and their students. That being said, I would remind readers who are interested in building community within their classroom and feeling overwhelmed that there is no expectation of perfection. We all enter the work from different points with different resources; however, it is important we keep working to disrupt those social norms and power dynamics that separate us from students and students from each other.

Our K–12 system is woefully inequitable. The ways we choose to operate our courses, especially freshman courses, can either reify or redress the imbalance of opportunities students experience in high schools. In New Orleans, I was once talking with a student about why it was so sad when teachers chose to leave our school. Bijon told me, "Ms. Winterer, white kids don't care when their teachers leave because they know they're just going to get another good teacher. They're like 'hey girl see ya later!' But, when our teachers leave, we don't know what we're going to get." We don't know where our students are coming from, but we can do our best to make sure all of them feel like they belong in our classrooms, mathematics, and our institutions. That starts with making connections and building community.

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2

St. Olaf's Big Tent
From Teaching Mathematics to Teaching Students

Deanna Haunsperger and Stephen Kennedy
with Ted Vessey

In the 1980s, mathematicians began to note that something remarkable was happening at St. Olaf. It had been growing since the early 1970s, but it was taking hold and garnering attention in the mathematical community. While many mathematics programs were happy to have 3–5% of the graduating class of their institution as math majors, St. Olaf was graduating 15% of its class every year in mathematics. While many mathematics undergraduate programs imagined that their purpose was training students to go to graduate school in mathematics, faculty at St. Olaf intentionally built a departmental community where all students were welcomed to study mathematics, regardless of whether or not they were interested in graduate school; it was their "big tent philosophy."

The start of a new era: If you build it, they will come

When Ted Vessey arrived at St. Olaf in 1970, Dick Kleber was the chair of the mathematics department, and the young faculty included Lynn Steen, Arthur Seebach, and Loren Larson. Vessey was impressed that, unlike his experience in other departments, these faculty knew their students' names and greeted them on campus. Department meetings were filled with faculty talking about what was best for the students. Not long after he arrived, Steen and Seebach began talking about undergraduates trying their hands at actual research—something heretofore considered impossible in mathematics. The department was bustling with ideas and excitement; a real departmental community was emerging. Loren Larson later said of his colleagues, "As a result of their leadership we changed the emphasis from teaching mathematics to teaching students, and this made all the difference."

Here we draw from an interview with the consummate story-teller Ted Vessey to tell the story of how, during the 1970s and 1980s, the St. Olaf Mathematics Department intentionally built a welcoming community and watched students flock to it.

The italicized sections below are gently-edited excerpts from an interview with Ted Vessey in 2009.

New ideas at St. Olaf

I was very interested in St. Olaf as they had about as many majors then, they had about eighteen a year, as they did in Milwaukee. And I asked them about how it was we had so many majors, and I remember as if it was yesterday, Lynn [Steen] saying, "Well, at a liberal arts college you have to major in something. You know, there are no professional schools here, we don't even run pre-professional programs. You have to major in something." And that discussion morphed into "What's the best thing to major in for a student who doesn't know what she wants to do?" And we all thought, of course, mathematics because you can use it everywhere. After several department meetings we had this exciting idea of "wait a minute, we should let people know about this." We had some very good students in those early days. And as a young faculty, we were attractive to students; they liked us as people.

Then Lynn had another discovery that I think had a lot to do with our successes there. Lynn had come in one day and said out of nowhere, "You know, the number of students in a given class who take mathematics every term is a monotone decreasing sequence. Every term you lose some of them." And he was concerned about the students who were going to be with us for three terms. He says, "Is all we want them to learn—calculus? Is calculus so central to what we do that we don't even teach them to do anything but calculus for three terms?" Well, I was teaching the honors multi-variable course. And I taught a baby linear algebra course to my multi-variable students so we could appropriate notation, we could use matrices, talk about derivatives. And I said, "Let's teach linear algebra first." Then if you want to go off and do something like economics, well you've seen linear algebra. And I can use it in multi-variable calculus. Everybody said, "yeah, why not?" And I'm convinced that of all the decisions we made when we were just going to upset the applecart and see how things go, that was the best one. Linear algebra is such a wonderful subject. Most students in those days started with a full year of calculus; linear algebra was first semester sophomore year. But we would have 75 kids in linear algebra. And there are more 'aha' moments in linear algebra than any course before or after. St. Olaf had a very, very strong pre-med program full of bright students who liked math and science, and normally they were taking organic chemistry alongside linear algebra. Now, I'm here to tell you, one of those courses is more fun than the other. And I think we seduced half the pre-meds into becoming math majors.

Building the department

After a while we did try to seduce people into majoring in mathematics. St. Olaf graduates 700 people a year, and we had eighteen majors in the math department. To get into a school like St. Olaf, these kids are good at everything. Why don't we see if we can get more of those students studying math? There's selfishness about this, and I don't understand why programs who turn up their noses at half their majors don't understand this: when you have more majors, you have more students, and when you have more students, you have more classes, and when you have more classes, you get more faculty. That's how your department grows, but it starts with getting more students. If all the students go away at the end of their required one course, well, then you'll be stuck with six, seven people. There were seven faculty in the

department when I started. And when I was done being chairman there were eighteen in the department. And that was strictly a tribute to the number of majors.
More and more majors meant our majors' classes grew, and we were running abstract algebra courses with twenty-five or thirty students.

With more majors, we could run seminars, too. I taught stochastic processes three or four times when I was at St. Olaf. While other departments were only able to offer a minimal major because they had so few students in their departments, our number of majors went from eighteen to thirty-five then thirty-five to fifty, and we could increase our number of upper-level math electives.

Also, there is a kind of geek factor about being a math major. I was a math/physics double—there's nothing geekier than that. But, when there are fifty or sixty or seventy kids in a class majoring in mathematics, ten percent or more of the graduating class, that kills the geek factor. It actually became fashionable to be a math major. We got lots of kids who were studying mathematics simply because they liked it, not because they had been told they're really good at it, and the more we massaged our major, the less it became a pre-graduate major. We wanted breadth; we were a liberal arts college, and we promoted double majors. You're an economics major? Well, of course you want to be a math major. Physics majors are a given, chemistry majors, maybe. But economics? Economics and mathematics became the biggest double major on the campus. As the number of students grew, the excitement level grew. Some of my favorite students were B or C students; they had no interest in graduate school, but they just liked mathematics. Kids were taking complex analysis for no reason other than it was just an interesting subject. You gotta like kids like that, kids who find complex analysis a beautiful subject.

Surprising growth

As the number of majors grew from eighteen a year to 120, the department found something that worked. And they weren't sacrificing the kids who wanted to go to graduate

Math faculty (from left) Paul Humke, Loren Larson, Ted Vessey, and Cliff Corzatt at the Swedish Midsommer Celebration, 1980.

school; in fact, by having that many majors, they were able to offer a much broader and deeper curriculum. As outlined in the 1995 *Models that Work: Case Studies in Effective Undergraduate Mathematics Programs*, "Even though [St. Olaf] majors may enter the program with other options in mind, about 20% to 30% of graduates do go to graduate school. During the period 1978–88, St. Olaf College ranked 5th in the nation among liberal arts colleges in the production of PhD mathematicians."

It snowballed on us; we were never aiming for 100 majors. We came up with something called a "Contract Major in Mathematics," which was considered revolutionary on the face of it, but it wasn't revolutionary in terms of how it operated. A student would come in and say, "I want to double major in chemistry" and then you'd say "Well, you really need to take differential equations and you should take linear algebra, blah blah blah." There were five courses you had to take, and five you got to pick from. Even that wasn't fixed; we told students they could propose any contract they wanted, but hardly any of them came up with anything creative at all. It was a very important philosophical thing because when a student came in and said, "Dr Vessey, I think I want to major in math," we'd say, "Go get a contract form, bring it back, and we'll talk about this." And it was this period when you and the student planned his or her major; I told them, "It's not written in ink, we'll change it if you have to, but let's start out this way. And let's keep in touch." They really had this sense of belonging. Also, the St. Olaf Math Department had a lot of student graders; we were the second-largest employer on campus behind the food service. In fact, we put in the contract that you have to do something outside class: tutor, grade papers. It got very hard to find something for them to do after a while, but we wanted them to feel that mathematics was an activity more than just a collection of courses. And I think we sold that.

We thought it was important to rotate courses among the faculty; in fact, to avoid a dispute about who would get to teach linear algebra (or some other popular course) next, if you taught a course once you had absolute priority to teach it a second time because everyone wants to teach a second time. Then if you taught thrice, you went to the back of the row, and then anybody else could have that course. We encouraged, almost demanded, that people teach across the curriculum for several reasons. One was just that you learn a lot more about linear algebra when you teach differential equations and you learn a lot more about differential equations when you teach linear algebra. You become a better mathematician, and we wanted our students to see us as broadly-trained mathematicians, not 'he's an analyst, he's an algebraist.'

Faculty are an important part of the community

Vessey was chair of the department from 1975 to 1985 and again from 1987 to 1990. During that time, the faculty grew from seven to eighteen. Hiring strong faculty who embraced the vision of the department, particularly colleagues with an interest in and commitment to good teaching, formed an important part of the community-building. During those years they did not just have strong teaching faculty at St. Olaf, they had faculty who were active in editing and contributing to MAA publications and serving in leadership roles in the MAA, including President of the society. This level of involvement in MAA activities was particularly impressive for a small liberal arts college. The wide reach of the department reflected the broad view of professional activity fostered by the department.

Photo Credit: MSCS Academic Administrative Assistant E. Haberoth.

Some St. Olaf Mathematics, Statistics, and Computer Science faculty, fall 2017.

In particular, senior colleagues encouraged junior colleagues to get involved both in the department community and in the greater mathematical community. This emphasis created a dynamic flow of ideas into and out of the program.

Years ago we had to come up with a departmental statement on what the department considered professional activity. The easiest thing would have been to count pages in journals. However, Lynn Steen, who everybody knew was an incredible asset to our department, published one, count it one, research paper. He and Arthur published the Counterexamples in Topology *book based on a summer institute URP [the predecessor to REUs]. But Lynn was writing absolutely pivotal papers that appeared in the* Monthly *or appeared in* Scientific American *and we knew that what he did was important. So we said what we really want people to do was to be active. Doing things and getting out there and of course they should have some results that people can look at, but it was not just counting research papers. Lynn Steen, based on his brilliant writing, became President of the MAA. And then, you know, Lynn is so bright and so organized that he became a tremendous power in mathematics education. Lynn's out there, and it always says "Lynn Steen, St. Olaf College." Well, that gave us tremendous public image, and everybody who's anybody would come to St. Olaf. For a period of ten years, we had every significant mathematician in America who was interested in mathematics education come and visit us. And then Loren Larson started getting involved with the problems, and he became Problems Editor for* Math Magazine. *And we were doing* Telegraphic Reviews *in the* Monthly *with Carleton College, so between Carleton and St.*

Olaf every decent mathematics book written in a twenty-year period went into our libraries. This was a real asset to our department to identify closely with the MAA. We accepted that as professional activity. A lot of our history goes back to Lynn Steen and you know "you gotta major in something" and "do you really want to have three calculus courses?" Not all Lynn's ideas were great ideas. Someone once asked me what was the hardest part of being chairman. I said "Lynn Steen." They said "Why?" I said, "He's in my office every morning, he's got three ideas. One of them is brilliant, one of them is nonsense, and one of them might work and that's the one you think about all day long because he's coming back tomorrow."

Advice for other departments

When Vessey was invited to other institutions to talk to them about how to replicate this community in a different department, he would suggest they learn some new mathematics, even if they weren't going to be teaching it, or try changing up their curriculum. He wanted them to recapture the excitement they had when they were graduate students.

When we would visit other departments to advise them, we would look to find out if there was a person out there who considers it his job to protect the virginity of mathematics—to drive anybody but the A students away—because that's killer. I mean, killer. Even if you don't want to have a lot of students. It's an unpleasant thing to do, and mathematics should not be in the hands of a few people. It's just too wonderful of a subject, too powerful of a subject, too interesting of a subject.

When professional opportunities came along for our colleagues, we would ask, "Is there any way this is going to benefit our students?" If so, we say yes! Now a lot of schools won't do that because there's no publication at the end of it; there's no payoff. But if we see a benefit for our students, we'll do it.

I was on a panel in the 1980s with three chairpeople from successful departments where we talked about what we did, and someone said, "It seems like you people spend a lot of time eating with your students." We had a turkey roast in the fall; we had a pig roast in the spring; we had all this food. I talked about the To Be Or Not To Be event [a fun-filled hour telling potential majors the importance and joy of mathematics and the possibilities it creates for

Photo Credit: MSCS Academic Administrative Assistant E. Haberoth.

St. Olaf Tailgating Party, 2017.

future careers], which is something I think is really worth doing: the students will get fired up because you're fired up, and they look around and there's a room with 150 seats that are full of people wanting to major in math.

Epilogue

Those young folks with bold new ideas who led the department in the 1970s and 1980s have all since retired. However, the vibrant community of students and faculty they built in the St. Olaf Department of Mathematics, Statistics, and Computer Science remains quite strong, graduating 65–90 math majors, 45–55 statistics and data science concentrators, and 25–30 computer science majors each year. This ongoing consistent success highlights the value of an intentional effort to build a department that welcomes all students and engages them beyond the classroom.

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3

Todxs Cuentan en ECCO
Building a Mathematical Community

Federico Ardila-Mantilla and
Carolina Benedetti-Velásquez

Aprendí que para uno encontrarse tiene que buscar en la raíz. … Aprendí que no soy sólo yo, y que somos muchos más. —*Grupo Bahía*

What is ECCO?

The Encuentro Colombiano de Combinatoria is a biannual gathering of students and researchers from Colombia, Latin America, California, and many other places. It is a two-week long summer school, featuring mini-courses by experts, collaborative problem workshops, research talks and posters, open problem sessions, a discussion panel, a hike, and visits to some of Colombia's legendary salsa clubs. It is also much more than a summer school, and we hope to capture a bit of its spirit in these pages.

ECCO is designed to give **every** participant opportunities to interact closely with people at all stages of the mathematical career. We do our best to build a very professional and very warm atmosphere. We are collaborators and we are also a community.

The Encuentro started as a small gathering for combinatorics students in Colombia and the San Francisco Bay Area. They had taken classes together, as part of the SFSU–Colombia Combinatorics Initiative described in [1], and it had become clear that they wanted to meet in person, build closer ties, and find ways to collaborate.

Since then, ECCO has broadened and gained a strong reputation. Students from many different countries now attend, and combinatorics experts also ask to participate. We communicate our goals clearly. This is not a regular conference; it is a school and an e***ncuentro***: a coming together. We ask experienced researchers to do problem sets with the students, to present research questions that they would like help with, to offer advice, and to join the dance floor at some point. They have been wonderfully helpful and inspiring mentors, they have recruited students, and—perhaps most meaningfully to us—several have mentioned that their experiences at ECCO have influenced their work at their home institutions.

As one becomes more experienced organizing events, one becomes more conscious of their shortcomings. ECCO is certainly an imperfect event. After seventeen years, it is still an event under construction, and we hope it continues to be. But ECCO has been tremendously inspiring and energizing to us, and has taught us a lot about what it might mean to truly find community and belonging in a mathematical space. The goal of this article is to share a few of the lessons that we have learned from helping to build it.

Community Agreement, Part 1

When prospective participants are applying to ECCO, they encounter our Community Agreement. The first part reads:

> **A rewarding experience for all.** *The Encuentro Colombiano de Combinatoria aims to offer a rewarding, challenging, supportive, and fun experience to every participant. We will build that rich experience together by devoting our strongest available effort to all ECCO activities. You will be challenged and supported. Please be prepared to take an active, critical, patient, and generous role in your own learning and that of the other participants.*

When we meet in person, we start ECCO by reminding everyone about this agreement. We ask people to get in pairs, read it out loud to each other, and spend a few minutes discussing it: What stands out to you about this agreement? What can it look like to put it in practice?

We're not gonna lie. While some participants jump right in, many look confused, and if we are reading their body language correctly, a few seem to think: *I can't believe you are asking me to do this; what am I, a kindergartener?* But we insist. Everyone participates.

To initiate a dialogue, we ask each group to underline a few words in the agreement that resonate with them, and share them with everyone. Some are excited that they will be challenged; some that they will be supported; some point out that the combination is crucial. We discuss how to be productively critical of each other's work and what generosity might mean in a mathematical setting. We talk about how sometimes we are very good at being patient with others, but not so good at being patient with ourselves.

We wrote this agreement to communicate, from day one, the kind of space we are trying to build collectively. Johan, one of the participants of Días de Combinatoria,[1] shared with us an experience that became an unforeseen consequence of the agreement. He told us that reading it on the webpage of Días was the push he needed to apply, and to attend; for the first time, he felt he was welcome at an event like this.

Community Agreement, Part 2

The second part of the community agreement reads:[2]

> **A welcoming experience for all.** *ECCO is committed to creating a professional and welcoming environment that benefits from the diversity of experiences of all its participants. We will not tolerate any form of discrimination or harassment. We aim to offer*

[1] The Días summer school is one of the offsprings of ECCO.

[2] This part of the agreement was based on a code of conduct written by Ashe Dryden, a former programmer turned diversity advocate and consultant; see ashedryden.com.

equal opportunity and treatment to every participant regardless of their mathematical experience, gender identity, nationality, race or ethnicity, religion, age, marital status, sexual orientation, disability, or any other factor.

Behavior or language that is welcome or acceptable to one person may be unwelcome or offensive to another. Consequently, we ask you to use extra care to ensure that your words and actions communicate respect for others. This is especially important for those in positions of authority or power, since individuals with less power have many reasons to fear expressing their objections regarding unwelcome behavior.

If a participant engages in discriminatory or harassing behavior, ECCO organizers may take any action they deem appropriate, from warning the offender to immediately expelling them from the event.

If you are being harassed, you feel uncomfortable with the way you are being treated, you notice that someone else is being harassed, or you have any other concerns, please contact Carolina Benedetti or Federico Ardila immediately. If you prefer not to speak in person, you may e-mail us (anonymously, if you wish) at the account _____@_____._____, which only Federico and Carolina access.

Again, we make sure everyone actively engages with this text, reading it out loud in pairs and discussing it, awkward as they might find that. We are direct: social events form an essential part of ECCO, and we explicitly ask participants not to use them as excuses for romantic advances. We bring together more than 100 strangers from many different cultural backgrounds for an intense shared experience; it is essential to have an agreement that clarifies expectations and gives the organizers the power to react to potential incidents.

We have co-created these community agreements with our students; our hope is to reach a collective understanding that is actually ours, that everyone is committed to as a whole. The critical feedback of participants has helped us strengthen our prevention and intervention protocols. We plan to add a short training on bystander intervention to the schedule of future ECCOs; this training helps participants recognize potentially harmful interactions and intervene to prevent them from escalating. We need to understand harassment and discrimination as community issues, and not individual issues, if we want to truly transform the harmful practices that our societies have normalized.

In the 'Any additional comments?' question on the exit survey of ECCO 2018, almost all participants who identified as women and/or LGBTQ+ praised the community agreement, and several said they would like to have one in all math events. Two participants wrote:

I thought the community agreement was an excellent idea. The openness allowed us … to make a giant community out of everyone, which made the conference very special. I felt I could finally be myself after years of feeling caged in.

We made an agreement to acknowledge each other's differences and try our best to create a positive experience for everyone and it worked! We came together and did math without fear or judgment. It was so much fun! I think that the community agreement and the leadership of the organizers, TAs, and Colombians were driving forces behind making that possible. We all played a part by putting our hearts into creating the environment we were longing for. I left feeling fired up about bringing ECCO home with

me. I would love it if all of my classes started off with a community agreement at the beginning of the semester.

A senior participant later told us: *I was very surprised at first, and looked at [the agreement] as an oddity. Then I remembered what it was like being a grad student at conferences and all the weird guys I had to avoid. So I figured, yeah, why not?* Another participant, who had been assaulted in a mathematical space before, told us that she simply does not attend conferences that do not have a plan to ensure her safety.

Mathematics has lost too many people—primarily women and people of color—to harassment and discrimination, and silence has never protected the victims. Perhaps by sharing with you how we are confronting these problems in our context, we may help you confront them in yours.

Breaking power structures

In any group of people there is a hidden power structure that influences who leads the discussion, who participates, whose voices are listened to, and whose ideas are seen as important.

Our activities are most successful—for teachers and for students—when we are able to disrupt those power structures as much as possible, when every participant feels that their presence is important and their thoughts are valuable. We try to do this constantly, in several ways; a particularly successful one occurs outside of the classroom.

On Saturday nights, ECCO moves to the dance floor of the best salsa club we can find. The truth is that many of our international experts look a bit intimidated when they first walk in. For most of them, this is not the kind of place they visit often, if ever. Few people at the *discoteca* look like them; they might feel like they don't really belong there.

Very soon, the students approach them and invite them to dance. They don't accept "I don't know how to dance" for an answer; they teach them, patiently, kindly, from the beginning, or just persuade them to dance as they will.

We won't pretend our guests become expert dancers overnight; that really does not matter. But they always seem really grateful to the students who make sure they are com-

Photo credit Andrés R. Vindas Meléndez.

Lecturers and students on the dance floor.

fortable, who guide them through a few steps, and who probably help them find a bit of freedom inside their body. Some of us have known these professors for years and we get to see a smile that they have never shown us before.

We like to ask our course instructors to keep in mind the feeling of discomfort they might have had entering the *discoteca* and the feeling of growth and joy they hopefully had walking out. Many ECCO students—who have never met so many accomplished mathematicians, who may have never attended a math conference before—are probably feeling a similar discomfort when they walk into the classroom. We want them to have that sense of belonging, growth, and empowerment when they leave. Since the professor was vulnerable in front of the student, the student can more comfortably say "I don't understand, can you explain this to me?" when needed. Since the student showed generosity and patience on the dance floor, the professor naturally shows a similar generosity and patience in the classroom.

> *We must return ourselves to a state of embodiment in order to deconstruct the way power has been traditionally orchestrated in the classroom.* —bell hooks [4]

The dance floor is one of the most democratic spaces of the tremendously unequal societies we live in. At ECCO it is a place of joy, and also a place of pedagogy, for professors and students alike.

Problem workshops: thinking simply about deep things

Mathematically, ECCO aims for a low-floor, high-ceiling approach. We want the courses and activities to be designed so that everyone is able to engage with them at some level, and no one runs out of questions to explore. Every participant should find interesting things to learn. This is perhaps best exemplified in the way that problem workshops are structured.

Each mini-course meets four times, and each 60-minute class meeting is followed by a 90-minute problem workshop. People self-identify their level of expertise, and we split them into groups as heterogeneously as we can. A typical group will include a professor or postdoc, a graduate student in combinatorics, and two undergraduates with scarce combinatorial experience. Many participants speak very little English, and many speak very little Spanish, so everyone has something to learn and something to teach. We offer materials in Spanish or English and the unofficial language of mathematical discussions is Spanglish. People are welcome to use the language they wish. Interestingly, many choose to communicate in a foreign language for the first time since this is their opportunity to try it.

The first problems on each list ask people to carry out a small example, to ensure that everyone understands the key constructions or results in the class. The last few problems on the list can be very challenging and may take days or weeks to solve.

We ask each group to keep in mind our community agreement: how can they make the problem session rewarding, challenging, supportive, and fun for every participant? The result has always exceeded our expectations.

We realize this approach is unusual. Occasionally, it faces some resistance. A few of the more-experienced participants have asked: "Why don't you let the beginners work on the easy problems together, and we can focus on the hardest problems?" But this is how these experts have been operating for most of their career. Why not learn something new?

It is very rare for an undergraduate to collaborate with an expert of one field on questions about a different field and see: *Experts struggle too! How do they productively struggle?* These are very valuable lessons for the undergraduates. It is also very rare for an expert to collaborate with a relative newcomer to mathematics as equals. When they find a way to do it, they inevitably deepen their understanding of the subject.

The last few minutes of the problem workshop are spent sharing solutions. We ask the people who are usually very comfortable speaking up to make space for others. We invite the least-experienced or the least-vocal participants to present their work—they are the ones who can grow the most from doing so, and with the right atmosphere and maybe a bit of extra encouragement, they are usually happy to speak.

Andrés Vindas-Meléndez, who was a master's student at the time, described his experience:

> *The exercises were mathematically meaningful, but what is noteworthy is that all group members played an active role in reaching a solution and understanding of the concepts. I observed that the more experienced mathematicians went directly to thinking about the abstraction of the problems, where the younger students emphasized a more concrete approach to exemplify the theory occurring in the problem. Of course both ways of thinking are valuable.*

This reminds us of Gelfand's request when encountering a new mathematical topic:

> *Explain this to me in a simple example; the difficult example I will be able to do on my own.* —Israel M. Gelfand

Satisfying this request can be very challenging for beginners and experts alike, and it can also be surprisingly rewarding and enlightening. The celebrated Ross Mathematics Program extols the value of thinking deeply about simple things. We agree wholeheartedly and propose the counterpart as well: there is a tremendous amount to be learned from thinking simply about deep things.

Universal design

Mathematicians from overrepresented groups in mathematics often ask "Why do you need these math conferences for minorities? Don't we all do the same mathematics?" To try to answer, allow us to digress for a moment.

Let us share an embarrassing confession: The first time we rode a public bus in North America, and someone in a wheelchair got on, we could not believe our eyes. Are all 50 of us really going to wait all this time for one person to get on? Did the city really spend all this money putting all this equipment on every bus for such a small percentage of the population? We both grew up riding the ramshackle buses of Bogotá, jumping in and out of them while they were still in motion, collecting frequent minor bruises along the way. We should have known better.

The term "universal design,"[3] coined by architect Ron Mace, describes the concept of designing all products and built environments to be aesthetic and usable to the greatest

[3] We would like to thank May-Li Khoe for teaching us about universal design and its wide applicability.

extent possible by everyone, regardless of their age, ability, or status in life. What may be unintuitive about universal design is that, what may seem like designing for a small minority, ends up being a better design for the majority. In fact, once it becomes widely used, it is no longer seen as serving special needs.

We often forget that sidewalk ramps were installed in every US city thanks to the Americans with Disabilities Act of 1990, after decades of activism. They were originally designed for people who use wheelchairs to go on and off sidewalks easily. Today, everyone uses them: a kid on a tricycle, a parent with a stroller, a traveller with a suitcase, a skate boarder, or the two of us when we were dealing with injuries. Everyone benefits from them.

With this in mind, let us propose an analogy:

> *Mathematics education cannot truly improve until it adequately addresses the very students who the system has most failed. … We need a central focus on students who are Latinx, Black, and Indigenous …, developing practices and measures that feel humane to those specific communities as a means to guide the field.*
>
> —Rochelle Gutiérrez [3]

This does not come naturally, or without some opposition. Sexism, racism, classism, and centralism often lead to a small, homogeneous group of students being valued more than the rest, tacitly or explicitly. Academic elitism centers the voices and interests of the "top" students from the "top" schools, whatever "top" might mean. Furthermore, in Colombia, we always seem to put the needs of our foreign guests above our own.

At ECCO we are intentional and unapologetic about focusing on the needs and interests of the local students, the less-experienced students, and the students from regional universities that have less access to activities like this. It is our belief, and our experience, that when we find practices and structures that truly serve these students, we are doing much more than serve these students. We find practices and structures that benefit the wider mathematical community.

For example, we must confess that the organizing committee had not explicitly thought about the experience of the LGBTQ+ community at ECCO. But our struggles are connected, sometimes in ways that we do not foresee. Postdoc Aram Dermenjian wrote:

> *The single biggest reason I loved this conference was the diversity and inclusiveness. In recent years I felt like the only gay person doing mathematics. I've started to feel more and more lonely in my math community. All my friends are amazing, and they always try to make me feel welcome, but it's just not the same.*
>
> *Having a community agreement allowed everyone to be open about themselves allowing queer people to be out.*
>
> *It gave me the confidence to do something I had never done before. I invited my math friends at ECCO to a gay club. Sure, more than half of us weren't gay, and sure, the gay club wasn't that amazing, but just being out, in a gay club, with mathematicians … was amazing. I felt I belonged.*

Professor Viviane Pons wrote:

> *One question arose from the students: why do professors come and teach at ECCO? They saw clearly what was the gain for them, but the reason we would spend time and*

The future: Días 2017 alumni at ECCO 2018.

energy there was not clear to all of them. So let me tell you what I (and the scientific community as a whole) gain from that investment. I can help shape the academic world to something better and to something I like. Being part of ECCO is one step in this direction, because that is the kind of math community I want.

The Colombian way

Worldwide, people have (accurate or inaccurate) ideas about the "French style," "Hungarian style," or "Japanese style" of doing mathematics. In a country that is relatively new to research in mathematics, perhaps we still have the opportunity to shape what "Colombian mathematics" might look and feel like.

Many would argue that mathematics does not distinguish a person's culture or nationality. Unfortunately, this widespread belief has led many of us to feel forced to leave our humanity at the door and struggle to fit in with the dominant mathematical cultures and practices. But our cultures are too rich to be dismissed when we enter mathematics and dismissing them is a loss to mathematics itself.

> *Research has shown that creating learning environments that value and incorporate students', families', and community members' cultural and linguistic strengths into instruction creates a nexus to mathematics cognition. … Culture and mathematics learning are intertwined in that they are both transformed through everyday lived experiences and are shaped by those experiences.*
>
> —Michael Orosco and Naheed Abdulrahim [5]

We are not interested in patriotism, but we are interested in culture and values. How might we use the cultural practices of Colombian communities to positively influence the cultural practices of Colombian mathematical communities—or at least the cultural practices of ECCO?

Colombians pride ourselves in being good hosts, and making every effort to help our guests feel welcome and comfortable. We are proud of our food, our music, our *rebusque*, and our stories. At ECCO, these all end up playing a central role.

Colombia has a unique salsa culture, where each *salsoteca* has a wall full of hard-to-find vinyl records from the 60s and 70s—mostly salsa, cumbia, and West African music—and this is what the DJ plays all night long. People of all ages dance with their family, their friends, their coworkers, and with any stranger who asks to dance with them. No one does those fancy turns and slick moves they teach in American salsa lessons. Everyone sings along as they dance. At ECCO, we organize a visit to the *salsoteca* with the deepest music collection we can find. César gives everyone (foreigners and bogotanos alike) dance lessons, the venue gives us maracas and cowbells to play along (and they take them away if our rhythm is not on point), and everyone dances together. And once the dancing starts, it does not stop. Imagine a conference where participants work hard during the day, dance during the night, and get up fresh and early next morning all over again, for two weeks. Well, dancing drains some energy out of us, but it also fuels us to return to the conference the next day and give it our all. In the final survey, undergraduate student Eliana said:

> *I think that dancing is an important part of ECCO and it changes the whole dynamic in a very positive way. In Colombia, mathematics is danced.*

Colombians are used to working with a shortage of resources, and we have a strong culture of ***rebusque***: this means that in the face of difficulty, there is always an ingenious solution to be found within our means. The first time we organized a summer course in geometric combinatorics for undergraduates, we were advised by foreigners that Colombian students would not have the preparation necessary to understand these topics, that we should teach a basic course in abstract algebra instead. But, for better or for worse, a lack of preparation has never stopped a Colombian from trying to accomplish something. We don't really believe in deficit mindsets. This culture of *rebusque* shapes our conviction that even without a lot of experience with mathematics, if you are hard-working and resourceful, you can take a class about current research directions from the world experts in the field, learn from it, and contribute to it.

The final activity of ECCO is a panel discussion where we talk about personal issues that most of us struggle with at every stage of our careers, but we rarely or never talk about. Discussion ranges from everyday topics such as "What does a typical day in your life look like?" to more trascendental ones as "What tools have worked for you to deal with stress, anxiety, or a sense of not belonging in academia?" We choose a broad range of panelists, from professors to undergrads, from all parts of Colombia and the world. To be truthful, we are not big fans of math panels in general. Why does this one feel different to us? Perhaps it's the strong sense of community and trust that has been built by the end of ECCO that leads to a very honest conversation that does not shy away from strong emotions. Perhaps it's simply that people, and their stories, are really important to us. Daniel wrote:

> *(The panel) is one of the most relevant things at ECCO. Breaking with the idea of math as a selfish and lonely task should be a priority. Talking like human beings, with our emotions and conflicts, is fundamental. Unfortunately this is rarely done in academic events. Congratulations to the organizers for recognizing the need to humanize math and mathematicians. This was a cathartic experience.*

Photo credit: Natalia Saavedra

ECCO 2018 participants from six countries.

This *encuentro* is an intense mental, physical, and emotional experience. We seem to have a tacit agreement to store lots of energy prior to ECCO and budget a few days of recovery afterwards. We start as a bunch of strangers and end, with tears of joy, promising to keep in touch, planning our next *encuentro*.

What does ECCO wish to be?

For us, it is crucial to be mindful of **how** we engage with and produce high quality mathematics. Valuing and promoting respect and difference has been essential to the development of ECCO. We seek to create an environment where each participant is empowered to take the space that belongs to them and share their voice, ideas, experiences, and world views, inside and outside the classroom. More than a conference, ECCO has become a space where learning mathematics is as important as recognizing each other as mathematicians and as individuals. If we are aware of what makes us different mathematically and personally, we can take advantage of these differences to complement each other.

> *The difficult, but also essential part, is to value respect and difference positively; not as minor, inevitable nuisances, but as the elements that enrich life and encourage creation and thought.* —Estanislao Zuleta [6]

ECCO brings together a close-knit community of mathematicians who are spread out all over the world. This community has led to the founding of the Seminario Sabanero

de Combinatoria[4] in Bogotá, and it has strengthened our mathematical connections with ALTENUA[5] in Colombia, and with CIMPA[6] worldwide.

To achieve a more lasting effect, we also challenge ECCO participants to continue to mold their mathematical knowledge so that it can be used beyond the creation and understanding of science as a tool of positive societal and human impact. This has led to the construction of other mathematical communities that celebrate different ways of learning and help dehomogenize the concept of academia in Colombia. Examples include Días de Combinatoria[7] and Círculos Matemáticos.[8]

ECCO wishes to help build a strong and dynamic research network that collaborates regionally and internationally and produces very interesting mathematical work. We also wish to help create a culture of sharing mathematical knowledge with the public and using this knowledge to have a positive impact in all sectors of society. Finally, we wish to be very mindful of how we do this work, putting our humanity, our values, and the diversity of our cultures at the center of everything that we do. These are the goals that guide our work. In our minds, they are inseparable.

Acknowledgments

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[4] SeSaCo is a weekly seminar that rotates locations among five universities in Bogotá.

[5] ALTENUA is a research group in algebra and number theory with a very strong presence in many regions of Colombia.

[6] CIMPA is a nonprofit organization founded in France that promotes research in mathematics in developing countries.

[7] Días is a summer school in basic combinatorics, geared towards undergraduates who haven't had access to classes in this area. More than half of Días alumni, from 16 different universities in 9 different cities, went on to attend ECCO.

[8] Círculos is now a national program that helps high school students from public schools fall in love with mathematics in an inclusive, non-competitive setting.

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Federico Ardila-Mantilla is a professor at San Francisco State University and Universidad de Los Andes specializing in algebraic and geometric combinatorics. He is convinced that everyone can have joyful, meaningful, and empowering mathematical experiences, and that community plays a central role in making that happen.

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4

The Carleton SMP
Planning the Unplanned

Deanna Haunsperger and Stephen Kennedy

We're not sure when it happened. It probably wasn't between the minestrone and the Caesar salad, though it may have been. In fact, it must have been there all along, growing stronger, but we didn't notice until it hit us with full force at dinner one night in January 2005 at the Joint Mathematics Meetings in Atlanta, Georgia.

We had planned a reunion of the former participants from the first nine years of the Carleton College Summer Mathematics Program for Women (SMP).[1] Participants in our selective program were young women finishing their first or second year at a US college or university who were interested in, and had shown a proclivity for, mathematics. Our program was designed as an intense mathematical experience to give them the impetus, along with support and encouragement, they needed to go on to advanced degrees in mathematics. It was a four-week summer program, and we encouraged the participants to keep in touch with each other via email after they left. We had hosted small reunions at the Joint Meetings before—four or five of us gathered after the day's talks for conversation over drinks. That January, though, twenty-five former participants and nine former instructors and teaching assistants were at the meeting, so we planned a nice dinner out, not as class reunions from nine different summer programs, but as one big group.

When we arrived, most of the SMPers were already there, and the natural thing was happening. They were talking to each other. The group included women at different points in their careers, from different parts of the country, from colleges and from universities, some undergraduates, some graduate students, some professors. What they had in

[1] In 2014, the American Mathematical Society honored SMP with their "Programs that Make a Difference" award. This award recognizes "outstanding programs that have successfully addressed the issues of underrepresented groups in mathematics." SMP benefitted from support from the NSA for a few years and from the NSF for every year of its existence. Lloyd Douglas served as the NSF program officer for many years of the SMP and personally championed many successful programs for women and members of other groups underrepresented in mathematics. The authors would like to extend their most sincere gratitude to these organizations and, especially, to Lloyd Douglas for his skillful ability to increase access to mathematics. They would also like to thank Carleton College for its ongoing financial and institutional support over the years of SMP.

common was a love of mathematics and a summer spent in a rural Midwestern town, but that was enough. We didn't need to do any introductions. In fact, we couldn't because no one could talk over the roar of conversation. The hubbub washed over us—we heard them talking about choosing graduate schools, selecting advisors, doing research, figuring out how to fit a family into a career, and whether to choose a sauvignon blanc or a nice pinot grigio with the grilled shrimp.

Over the years we had heard from SMP graduates who had attended a conference or visited a graduate school and bumped into an SMP graduate from a different year. They had enjoyed the "small world" phenomenon and dropped us a line to report. We had not fully realized, until this dinner in Atlanta, that over the years what we had actually built was an incipient community ready to interact and support itself. It just needed a tiny push to get it going full strength.

Fewer women in mathematics

The numbers are familiar to everyone in mathematics: each year women earn nearly 50% of the bachelor's degrees in mathematics awarded by US colleges and universities. However, only about 30% of the PhDs in mathematics are awarded to women. The rate at which qualified women advance to graduate school and the rate at which they persist in graduate school are both lower than the comparable rates for qualified men.

Why do so few women (relative to men) pursue and achieve advanced degrees in mathematics? Although definitive studies on this problem have not yet been done, anecdotal evidence points to several causes. Often, women who are drawn to mathematics find it difficult to believe that they can have effective careers in the field. Few of their professors are women. The male students in the class seem to get more attention from the instructor and, for whatever reason, seem to dominate the classroom discussions with their questions and responses. Most students demonstrate a lack of awareness about women mathematicians. Thus, women studying mathematics often have to deal not only with the difficulties inherent in the subject itself, but also with the psychological and emotional problems caused by studying in this type of environment.

Our Summer Mathematics Program

Each summer from 1995–2014, eighteen first- or second-year undergraduate female or transgender math majors, selected from the 100–120 applications, came to Carleton for four weeks. During that time they spent three-and-a-half hours each weekday in a classroom setting learning mathematics they would not normally see as an undergraduate (such as Morse Theory, Coding Theory, Game Theory, Fuzzy Logic, Low-Dimensional Dynamics, Knots and Topology) from outstanding instructors, chosen for their ability to inspire in the classroom and engage students outside the classroom. Each instructor had her own teaching assistant, a former SMPer either heading off to graduate school or in the middle of a graduate program. The students did homework, took exams, and made presentations, but not for a grade; they did it for the joy of deeply understanding some interesting mathematics.

The students were, by design, kept very engaged. Beyond the classroom instruction, the students attended twice-weekly colloquia on a variety of mathematics subjects to give them a peek into the wider world of mathematics. They also participated in three panel discussions: "Making the most of your mathematics major" (including information on research experiences for undergraduates, study abroad programs in mathematics, courses they should be sure to take before applying to graduate school, math meetings they could attend, organizations that would enhance their careers in mathematics), "Applying, surviving, and succeeding at graduate school" (including information on teaching assistantships and fellowships, how to choose a graduate program, what happens in graduate school, general exams, choosing an advisor, and enjoying their graduate program), and "Non-academic careers in mathematics" (with panelists possibly including an actuary, a high school math teacher, a biostatistician from the Mayo Clinic, an operations researcher from Northwest Airlines, an epidemiologist, and others). On Monday nights they puzzled over challenging problems during a recreational problem-solving session where they learned about various national and local problem-solving competitions. All of these activities were meant to give the students a view of the mathematical community that exists outside their own college and give them some avenues to find where they fit into it.

As a priority, we worked to join the women into a cohesive community so that after they left Northfield, Minnesota they would still look to one another for support and encouragement. Each summer we planned social events—picnics, walks around the Twin Cities, an afternoon at the Minnesota Arboretum, game night, hiking at a state park, and canoeing on a local river—as opportunities for the students to grow closer together. Besides keeping tabs on the students' progress through the instructors and teaching assistants, one evening each week we held a group meeting of all the students and the director (often with cookies) to make sure no one was feeling overwhelmed by the intense nature of the program. By the time of the closing banquet at the end of the program, it was clear to us that the participants had cultivated deep and abiding bonds.

> *To learn about other women's experiences, to be encouraged, supported, to have so many people believe in me, and to connect with such brilliant and fun women was awesome!*[2]

> *I think it was amazingly fun. Not only that, but everybody was so friendly and intelligent. I never knew there were so many math girls out there like me.*

> *… probably the most lasting things that I will bring home from this program are the friendships and connections I have made with everyone.*

Facing, and conquering, difficult challenges together is the most effective way we know to form group bonds; that's why we insisted that our instructors challenge the participants to the limits of their abilities. The intense and rigorous intellectual experience combined with the supportive and enveloping social interactions forged our students into a vibrant sisterhood of mathematicians. We were very intentional about this strategy; it was the soul of our program. We thought of each of our summer programs as its own little community: women who knew each other and shared a common four weeks in Northfield, with the

[2] Unattributed quotes throughout this article are from end-of-program evaluations.

Carleton Summer Mathematics Program, 2010.

knowledge and stories that accompanied it. We were astounded and delighted to discover in Atlanta that in fact our nine distinct communities might easily meld into a larger, stronger community. This experience was an epiphany for us. We thought we had to play a more active role in manipulating a group into a community. But really we just needed to get these women together in a safe space and allow the community to form naturally. We also learned the value of a vertically-integrated community. We didn't need to find established women at various points of their careers to be a resource for our students—we already had SMP graduates at those points who were willing to offer advice. We learned that SMP women at all stages of their careers were eager to look back and lend a helping hand to women at earlier stages. Immediately after the Atlanta meeting we started to work on consciously constructing that larger community, leveraging that generosity and willingness to help.

> *It has been an extremely busy, frustrating, exciting, empowering, four weeks, and today is the final day. I have learned so much math and so much about math it is truly amazing. The whole secret world of mathematicians is one that I never really knew about, but now want to be a part of. These four weeks I have learned that 2+3 is not 3+2, a circle and a triangle are the same thing, a sphere is a two-dimensional object, and that the more useless the problem, the more mathematicians like it. I have also learned how to draw four dimensional objects on paper, yet still can barely draw two dimensional objects. My brain has been turned upside down, and I am excited to know that it will probably never be returned to its original orientation. The friends I have made here are ones I hope to never forget. It is amazing how strongly people can bond so quickly by spending hours discussing math. It is going to be hard to have to leave the people I met here, because I feel some connection to every one of them.*
>
> —Former participant's blog

As a college sophomore from a tiny school in the middle of nowhere, I arrived at SMP thinking that I would learn some mathematics for a few weeks in the summer and that would be it. Little did I know that I was joining a life-long community! I certainly learned some very interesting mathematics, but just as importantly (or more importantly?), I developed friendships and made connections with other women interested in math. It was at SMP that my instructor, Karen Brucks, asked me if I was planning to go to graduate school. It was the first time that anyone had asked me that question.… It was a life-changing moment in which I began to realize that I belonged to a mathematics community. —Becky Swanson, SMP 2001

Expanding the program through SMPosia

The tenth summer of the program, 2005, saw the inaugural "SMPosium," a three-day event celebrating the successes of SMP graduates who had completed their PhDs. This gathering was a direct outgrowth of our Atlanta epiphany. In the summer of 2005, there were twelve former participants and teaching assistants who had finished their PhDs. Of those, nine were able to attend the symposium. On the first day of the program, the visitors were introduced to the participants and four of them presented twenty-minute talks on their research, followed by a picnic for everyone involved for informal interaction. At the picnic, a number of participants approached the directors to say what an "inspiration" it was to have these women who've "made it" visit the program. On the second day, the other five participants gave twenty-minute talks on their research, followed by the panel discussion on applying, surviving, and succeeding at graduate school. The questions and answers were lively and upbeat. The panelists gave practical, honest answers to eager, thoughtful questions. These visitors weren't women on a poster designed to inspire, nor were they anecdotal evidence of women successful in mathematics passed down over generations of students; these were flesh-and-blood role models, sitting right in front of them, only a few years older than they were. A dinner reception for these current and former participants capped off the evening. The last day of the three-day event was reserved for hiking in the Minnesota Arboretum, during which time the participants and guests intermingled and walked and talked and made connections.

The SMPosium was an experiment, and it worked. As with the Atlanta reunion, former and current participants spoke easily with each other about undergraduate classes, graduate school, job searches, and family. On the second day, when the graduate panel started and the nine guests took their seats at the front of the classroom, one participant in the front row looked at the guests, with whom she'd been interacting for several days about math and non-math alike, and an awakening visibly crossed her face. She realized that they were no different than she was, just a few years older. She said to herself, in a voice quite a bit louder than she had intended, "Wait, they all have PhDs? This is so cool!" We agree; it is cool. And we looked forward every year to our next reunion to bolster the young and celebrate the triumphs—to catch up with our mathematical family.

I got a lot out of the program, but I think what I got out most was to see what it's like being in a mathematical community and realizing how much I enjoyed it. It was really great meeting all these people who are totally different from me, but we all still share

this common bond of loving math.… I just have this big fear that there is no future out there for me in math, but meeting all these other women who have succeeded, helps me to put those fears to rest.

It seemed to be working

Since our participants came to us when they had just finished their first or second year of undergraduate study, the time it would take them to finish a PhD would be seven or eight years after their SMP summer. We celebrated when Suzanne Boyd, a student in our first summer program in 1995, finished her PhD at Cornell in 2002. She wrote to our community:

This past year wins (by a mile) the "roughest/craziest/most frustrating year of my life" award. Applying for jobs, finishing my dissertation, and arranging to move all at the same time. If any of you out there will be finishing your thesis sometime in the next few years, feel free to give me a call and chat about the process. It's OK if we've never met before, just tell me you went to SMP.

We find that last sentence particularly gratifying. It testifies to the eagerness of the participants themselves to invest in the future of the community.

As more students began earning their PhDs, we felt like we were having success at encouraging these women to continue on to graduate school and have a successful experience there. A back-of-the-envelope calculation shows that SMP alumnae persist to a PhD at a rate much greater than that of non-SMP alumnae. Comparing the number of women entering graduate school in Groups I, II, and III departments of mathematics in the years

Carleton Summer Mathematics Program, 2013.

2001–2005 and the number of women finishing PhDs from those same departments in the years 2006–2010 shows that there is about a 26% persistence rate to PhD. The persistence rate to PhD for SMP alumnae from 1995–2005 who entered mathematical science PhD programs is about 63%.

This higher persistence rate was not a result of us cherry-picking women from the strongest undergraduate institutions in the US. Our participants who went on to earn PhDs came from a variety of undergraduate institutions including Holy Cross, Xavier, Gettysburg, Alfred, University of Akron, Kenyon, Kalamazoo, Pacific Lutheran, and Huntingdon. They were finishing their first or second year as an undergraduate, and we only had four weeks to teach them any mathematics. In that four weeks, however, they gained insights, mentoring, and a community where they belonged.

> *My summer at SMP helped me become both more logical and more creative in my thinking. It helped me learn how to grapple with new and challenging concepts. And it allowed me to develop these skills in a community that was rigorous and challenging while still fundamentally very supportive. I think that last part is what makes SMP so special, how the program challenges you while also affirming that you (as a young woman) belong in the field.*

Expanding SMP

A few years later, we had some funds left at the end of a grant cycle, and we wanted to create an opportunity to check in on SMP graduates who were in graduate school. We were seeing students in the middle of their undergraduate education in the summer program, then after they had finished their PhDs in the SMPosium. We wanted to check in on them in the middle. With the help of SMPers Jen Bowen, Katherine Crowley, Alissa Crans, and Pam Richardson, we started a Graduate Education Mentoring Workshop in conjunction with the Joint Mathematics Meetings (JMM). Once again, our alumnae stepped in and did community-building work. This workshop provided an opportunity for graduate students to get advice and mentoring on issues relevant to them during grad school. They also gave practice talks and received feedback on their presentations. This continued every January before the JMM for many years.

Around this same time, we were generally pleased with the SMPosium for SMP PhDs. The PhDs served as great role models for the undergraduates, but they weren't around them long enough. This observation led to the creation of Mathematicians in Residence (MiRs), an opportunity for SMPers to return for two weeks or a month. They would model, by their very presence, what it meant to be a modern woman mathematician. These MiRs would spend their days doing mathematics in a quiet, airy library at Carleton, and they would spend their evenings and weekends in social time weaving threads in the fabric of the students' community.

Our last addition to the structure of the program in its later years was to add an optional outreach afternoon to the already-packed schedules of the undergraduates. One afternoon during the summer the SMPers were invited to attend an enrichment program in a small town nearby. They played mathematical games with children whose families recently immigrated from Somalia, and at a nearby camp for children from low-income families, the SMPers had the children stand close together and grab hands with some-

one else nearby, then challenged them to untie the mathematical human knot they had formed. We made it an optional activity because we already stretched the SMP participants in many different directions. But, not to our surprise, when the sign-up sheet went around, all SMPers signed up to participate. They knew the importance of mentoring and community and wanted these kids to have a similar experience.

Our results

The young women mathematicians in our summer program immersed themselves in mathematics, living and working in a supportive community of women scholars (undergraduates, graduates, and faculty) who were passionate about learning and doing mathematics. We had three main aims for the program: to excite them about mathematics and mathematical careers, to provide them with some of the tools—psychological, emotional, and mathematical—they will need to succeed in a mathematical career, and to connect them to a network of fellow female mathematicians. We have been successful. Over the years, students reported on their post-program evaluations their renewed energy and commitment to mathematics. They also related their feelings of isolation at their home institutions and the joy they experienced with new kinships with sisters in mathematics.

The students returned to their home institutions eager to jump into their studies. They had a clearer idea of mathematics, a much clearer understanding of the mathematical community, and a vision of their place in both. Their increased awareness of various topics within mathematics led many to give talks in their home departments on the mathematics that they learned in the summer program. Most participated in research experiences for undergraduates, the Budapest Semester in Mathematics, or other further-enrichment programs. Later, they acknowledged how SMP helped prepare them to succeed at, and benefit from, those programs. More important than the knowledge and renewed excitement for mathematics, each of the students gained confidence in her ability to do mathematics.

This confidence building was central to the mission of the program. All of these students, and most of the other one hundred who applied each year, are intellectually capable of achieving an advanced degree in mathematics. Something other than intellectual capacity prevents many women from pursuing one. Our SMP experience revealed that heightened self-confidence and a supportive network of colleagues and mentors help keep young women from dropping out. These students returned to their home institutions knowing that women can and should do mathematics. They were supported by this knowledge and they carried the message back with them to influence their peers and their teachers.

> *I can honestly say that graduate school was such a pleasant experience because I knew that I was never alone and had the entire SMP network to support me during any obstacle that came my way.* —Jasmine Ng, SMP 2005

> *SMP is where I realized that I could be a mathematician and that this was a possible career path for me. Because of this program I discovered and attended Budapest Semesters in Mathematics. Because of this program I applied to and attended an REU. Because of this program, I went to graduate school in math. However, the most important thing SMP became to me is an extended math family. I never expected to be able to connect to so many wonderful math women, across all stages from applying to*

graduate school all the way to having "made it" in an established career. SMP isn't just a program, it is a giant supportive family. —Melinda Lanius, SMP 2010

The SMP community had an impact on the lives of the young women who came to our program—we still see the increased confidence, enthusiasm, knowledge, and mathematical sophistication. We still see the electronic messages they post on the program's Facebook page and the updates to the annual newsletter to let us and each other know what is happening in their lives—mathematical and otherwise. It is less clear to us how to measure this effect. We can never know how many would have gone on to productive mathematical careers without SMP. We won't know for some time how long and how far the momentum of SMP will sustain them in the face of adversity. We do believe that SMP made, and continues to make, a difference.

… beyond a summer program, which, in itself, was enriching and rewarding, [SMP has] created a network of confident and informed women in mathematics who constantly and consistently support, encourage, and enable one another. This web of connections has bolstered and emboldened so many women to pursue a career in mathematics and to persist when faced with the inevitable difficulties therein. I will readily count myself among these, and for that and so much more, I thank you.
—Kristin Courtney, SMP 2008

Of the 343 young women and trans men who entered our community when they were undergraduates, 122 now hold PhDs in the mathematical sciences. Eight more hold PhDs in cognate disciplines. About 80 more hold terminal master's degrees, and 25 more are still in graduate school. That is, over two-thirds of the students who came to SMP as first- or second-year undergraduates with some nascent interest in mathematics now hold (or are working towards) advanced degrees in the mathematical sciences. Funding SMP was an investment in the future of American mathematics, and it's still paying off, each year, with women finishing PhDs and master's degrees and entering careers in business, industry, and government. Interest has also been accruing on this investment: each of these women understand the value and importance of belonging to a community and mentoring its young, and they have gone on in their own ways to pay back this investment tenfold.

SMP was the beginning of my mathematical mentoring journey. I not only benefitted from my mentors, but simultaneously this mathematical community facilitated me becoming a future mentor. I now serve as department chair at a small liberal arts college, advisor to many math majors—but also as a part of the Posse Foundation as a faculty mentor to ten students. SMP gave me the motivation to sustain a graduate student mentoring program for eight years at the JMM, and now, an experiential learning program 'Women Who Count' at my own institution. I am forever grateful and proud to be a part of the SMP community. —Jen Bowen, SMP 1996

My SMP family is incredibly supportive. I always feel like the community wants me to succeed, and everyone will do what they can to make sure that happens. I gained lifelong friends, not just professional colleagues, through SMP.
—Pam Richardson, SMP 1999

SMP was a wonderful experience.… From the fascinating courses to the collegial environment, fueled by [an overall] spirit of generosity, inclusion, and joyous adventure of mathematics, I remember SMP fondly and credit it as a guiding force along my path to realizing a life in mathematics. Moreover, the positive effects of SMP did not end with the summer. [SMP has] an ongoing community through the SMPosiums and newsletters. Mathematics as a whole, women mathematicians in particular, and I personally, owe [SMP] a big thank you. —Rachel Maitra, SMP 1999

Defunding and the future

In 2014, the National Science Foundation chose to end the funding of a number of successful women's programs in mathematics including SMP. We can no longer invite young women to attend our summer program and become a part of our community that way. Instead, we hosted a morning workshop (supported by an NSF INCLUDES minigrant and by the Mathematical Association of America) at MAA MathFests in 2018 and 2019 for undergraduate women who are already attending MathFest to try to give them some of the same information, but in one morning, it's impossible to create the kind of community that persists for years.

It's unclear to us when SMP started to take off on its own; in the early years we were completely focused on each individual summer's group. We learned how to forge strong bonds within those groups but we never really looked at connecting across the years. We made small steps: we used SMP alumnae as teaching assistants each year, we occasionally staffed the graduate school panel with an alum or two, we invited back alumnae with PhDs to give colloquia. All this was done as much out of convenience and affection for the alums as for any other reason. But then we looked up and saw a flourishing community of eighty or a hundred new or nascent professional mathematicians ready to give back, and we provided the venue and the cheering section. We have inadvertently built something much larger than we initially intended, much stronger than we could have imagined. We're running alongside trying to keep up with this group of women who will influence mathematics and each other for the next half century or so and we couldn't be prouder of, or happier about, our serendipitous community.

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5

The Nebraska Conference for Undergraduate Women in Mathematics

Christine Kelley and Glenn Ledder

The Nebraska Conference for Undergraduate Women in Mathematics (NCUWM) was founded by the University of Nebraska–Lincoln (UNL) Department of Mathematics in celebration of the department's receipt of a 1998 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM). The department received that award based on its success in mentoring women graduate students at UNL. NCUWM builds on that success by providing a mentoring experience to women undergraduate mathematics students from across the country. Held annually since 1999, the conference has grown from 53 undergraduate participants to about 260 each year, and almost 4000 undergraduates have participated in NCUWM throughout its history.

Building a community of women mathematicians and others who support them formed a foundation for success for NCUWM. By showing each participant that she belongs to such a community and that there is a place for her in the larger mathematics community, the NCUWM inspires women to thrive and achieve their goals. This inspiration is not limited to the undergraduate participants. The professional mathematicians, graduate students, and faculty who attend also gain a renewed feeling of fellowship, a sense of belonging to a network of like-minded individuals, and a feeling of empowerment.

NCUWM encourages undergraduate women interested in mathematics, regardless of their major, and their faculty advisors to attend. While we do not exclude anyone from participation, we design the program with women in mind and invite only women mathematicians to participate as panelists and plenary speakers. Although the aim is to present graduate school and professional careers requiring a graduate degree as options for students, we do not restrict attendance to students who already know they want to pursue an advanced degree. Rather, we cast a broad net for students by advertising widely, recruiting actively, and employing an application process that aims to increase diversity in general.

Program goals and activities

NCUWM is designed to address issues that often inhibit many women from pursuing careers in mathematics, particularly undergraduate women whose classmates often include very few women, who have difficulty finding women as role models, and who struggle with self-confidence issues. The goals of NCUWM are

- **To arm undergraduates with knowledge about career options and educational programs in mathematics.** Many undergraduates are surprised to learn that people are paid to be graduate students, that there are significant differences in size, mentoring support, and research areas among graduate programs, and that there are jobs for math PhDs in industry and government. This insider knowledge encourages students to think more broadly about their study of mathematics and their futures.
- **To promote self-confidence in their abilities and choices.** A recurring theme in talks and panels by graduate students, recent PhDs, and prominent mathematicians alike is the importance of developing self-confidence in one's mathematical abilities and in life choices.
- **To build a network of mentors and peers with related goals and interests.** Many undergraduate women who attend NCUWM have few female mathematics faculty as role models and few female peers to establish a network of support. Women of color often find even fewer role models in whom they can see their future selves.

NCUWM achieves these program goals through activities motivated by a coordinated set of strategies:

(1) **Provide women at multiple career stages as role models.** Some undergraduates with high self-confidence and prior research experience benefit from seeing prominent mathematicians as role models, while for others it is much easier to look for inspiration from women who are only one or two professional steps ahead of them. Thus, we invite guests who span a range of career stages. Each conference has two or three prominent mathematicians as plenary speakers, several women in the early stages of their professional careers as members of panels on career experiences, and several mathematics graduate students as members of a panel on the graduate school experiences. The conference also attracts a cadre of faculty, mostly women, who attend with their students. These women function informally as mentors and role models for junior faculty as well as for the graduate students and undergraduates. We also structure our conference program so that the more-experienced undergraduate students serve as role models for the less-experienced students.

(2) **Provide a group of potential role models that is diverse in every possible dimension.** Each undergraduate comes to NCUWM with her own personal experiences, issues, and sense of identity. Conference organizers deliberately invite a diverse group of speakers to promote an inclusive environment and to provide a variety of role models who appeal to different groups of students. We also deliberately look for diversity in non-demographic dimensions. The invited professionals

come from a variety of work environments, including academia, industry, and government. Some have followed a traditional path from college to graduate school to postdoc to junior faculty. Others have deviated from this more standard track by briefly pursuing careers outside of mathematics or focusing on alternatives to a full-time career. While some of our guests have careers focused on mathematics research, we also have guests at each conference for whom a mathematics background has led elsewhere, such as a college presidency or a partnership at a financial institution, or whose love of mathematics is expressed through a career focused on another field such as computer science or engineering. The resulting mix makes it much more likely that each undergraduate will see someone whose experience resembles hers and who can offer advice on issues of concern to her.

(3) **Have participants take an active role in their own mentoring.** NCUWM activities are designed to feature mentor–mentee interaction rather than passive dissemination of information from experts. Activities at the beginning of the program are specifically designed to help the undergraduates see the invited guests as approachable, while activities later in the program are designed to give students time in small groups with mentors of their choosing. Small group activities focus on a variety of different issues and students can choose which of these to attend.

(4) **Build a sense of community among peers.** Small group activities on focused topics help the attendees find peers with similar interests and issues. The informality of many conference activities helps attendees form personal connections, and the self-contained venue fosters connections during conference breaks and after hours. We hope these new friendships will continue after the conference has ended and provide peer relationships for the women long after they return to their home institutions.

(5) **Focus on general ideas, not specific institutions.** Each year we invite several graduate programs to participate by sending a graduate student panelist. These students talk about the issues that informed their choice of graduate school and describe aspects of their graduate school experience, but they do not advertise for their particular institutions. We provide brochures for programs for women, such as the EDGE program, but not for programs at specific mathematics departments. Only a few visiting faculty come from PhD-granting institutions, and they refrain from treating the conference as a recruiting opportunity. Students who have already expressed an interest in our department have opportunities to meet members of our faculty, but we do not make any effort to recruit other students to our department. Part of the value of the conference for the undergraduate attendees is the clear emphasis on providing a broad range of options rather than recommending specific ones.

Diversity and the application process

Originally, NCUWM accepted any undergraduate women who wanted to attend. When the conference grew to where we had more applicants than space, we began to limit the number who could attend from any one home institution, first to six and then to

Photo Credit: Marcella Manivel.

Students (front) Marcella Manivel, Dhamar Magdaleno, and Abby Loe with their faculty advisor (back) Kate Hake enjoying the NCUWM.

five. Registration was open to all, subject to this restriction, on a first-come, first-served basis. Over time, we had to have shorter and shorter registration windows, leading to the paradoxical situation in which our desire to make the conference open to all benefitted those students who had savvy mentors familiar with the conference, while those who had the least mentoring at home were unaware that they had to register very quickly. When the registration for the 18th annual conference in 2016 had to close after just one hour, it became clear that we needed a new policy.

The current plan begins with a two-week period when students submit applications as "presenters" or "non-presenters." Potential presenters must provide a tentative title and abstract. We limit students to a single conference attendance as a non-presenter so as to maintain as many slots as possible for first-time attendees. The selection process begins with a decision about presenters. Once presenter slots have been assigned, we allocate non-presenter slots to home institutions, rather than to individual applicants.

We recommend that students who attend the conference give a presentation at their home institutions to share what they learned with others, and some institutions have made this a requirement for their students to receive partial funding.

We try to have as diverse a student group as possible, subject to the selection protocol outlined above. We direct additional advertising to historically black and Hispanic-serving institutions because the best way to assemble a diverse cohort is to have a diverse pool of applicants.

Conference format

We include a variety of elements that fit together and emphasize the strategies outlined in the previous section to achieve the conference goals. Each two-day conference includes two or three plenary talks, approximately 48 talks by undergraduates, an undergraduate poster session, three panel discussions, three sets of breakout sessions, and several networking opportunities. Many of the activities that are now part of NCUWM have been present since the inaugural conference, including the plenary talks, student presentations, and panel discussions. Others have been added or modified over the years in response to feedback from attendees.

Plenary talks

The primary criterion for plenary speaker selection is professional success; however, we specifically look for successful women whose vita demonstrates an interest in mentoring. At least one of the two or three plenary talks is given by a prominent academic woman mathematician who demonstrates exceptional research contributions in mathematics or a related field using mathematics. At least one is given by a woman who is prominent in a career for which an education in mathematics has been a point of entry. Women who fill this second slot have had a variety of careers that include at least some component outside of academia, including government, industry, and administration, and have demonstrated exceptional contributions in research or national leadership. Plenary speakers in the first 21 years included eight members of the National Academy of Sciences (including three who were elected in 2019), one member of the National Academy of Engineering, seven Society for Industrial and Applied Mathematics (SIAM) Fellows, 22 American Mathematical Society Fellows, nine presidents of the Association for Women in Mathematics, a president of the American Mathematical Society, a director of the Fields Institute, and a college president. The plenary talks highlight a variety of career experiences, mathematics areas, and personal stories about obstacles including difficulties finding acceptance in mathematics or coping with low self-confidence. Many of the talks also illustrate the excitement that mathematics has brought to the speaker's intellectual life.

Undergraduate talks and poster presentations

The two-day NCUWM event includes five concurrent sessions of talks by undergraduate students. The schedule accommodates at least 48 presentations at twenty minutes each. These talks require an element of original research, which the undergraduates have done at REUs or as honors projects. For many of the undergraduate speakers, NCUWM is the venue for their first professional talk. The conference strives to provide a friendly, supportive audience so that this experience is a positive one. To accommodate an increasing number of women prepared to give a presentation, the conference added a poster session to the regular schedule, which is a good starting point for first-time NCUWM participants to present their work without the intimidation of a formal talk. Poster presenters also have the opportunity to talk in depth about their work with faculty and peers. Since 2015, at least half of the undergraduate women in attendance each year have been presenters (some talks and posters have joint presenters).

The undergraduate presentations showcase a variety of research topics and levels, and the presenters are proud of and visibly excited about the results they obtained. This shows the more junior participants how exciting mathematics can be and can spark a "Hey, I could do that, too!" reaction, thus encouraging them to apply to undergraduate research programs and consider graduate school. Many of these junior participants return to NCUWM in a subsequent year as presenters. Through these presentations, the advanced undergraduates serve as role models for the junior undergraduates and are also recognized for the work they have already accomplished. This success helps prepare them for graduate school by providing an opportunity to add a conference presentation to their record and by building their self-confidence.

Panel discussions

Panel discussions are whole-conference events on topics of general interest. "Careers in Mathematics" and "Choosing a Graduate School" provide insider knowledge and insight, largely through a question-and-answer format, from mathematicians at various career stages. The careers panel features two mathematics professors from academia (one from a research university and one from a smaller undergraduate institution), PhD-level industry or government laboratory mathematicians, mathematicians from the NSA and/or NSF, and a master's-level industry mathematician. The graduate school panel consists of six-to-eight invited graduate students, from different stages and types of mathematics graduate programs, who share advice on what to look for in a graduate program, how to decide whether a graduate program suits your needs, how to succeed in graduate school while maintaining some non-mathematical aspects in your life, and how to find a PhD advisor. There is also a lighthearted panel called "Random Bits of Advice" during the banquet on the opening night. This panel consists of three to four invited professional mathematicians, including the plenary speakers. We make sure that there is at least one panelist who we can count on to set the tone for an open, friendly, and fun conference atmosphere. We choose a moderator who knows the conference well and will jump into the discussion when appropriate. Participants can ask any type of question they wish. Having this panel very early in the conference identifies the plenary speakers as approachable, thus facilitating subsequent interactions.

Breakout sessions

Breakout sessions are small-group discussions with roughly 20–35 participants per group and are regarded by many participants as one of the most valuable components of NCUWM. Participants attend three sessions on topics such as "Research in Math," "Being a Member of an Underrepresented Group in Mathematics," "The Confidence Gap," "Math Club Activities," "Applying to Graduate School," and a more recent addition, "Dealing with Microaggression." The breakout sessions provide a less formal atmosphere for students who might be shy about speaking up at a full panel to ask questions and provide time for more lengthy responses. They also tailor the conference to individual needs with discussions on topics that are of great importance to a small number of participants, such as "Being a Graduate Student and Parent." Each breakout session has two official facilitators who help keep the conversation going, but anyone attending the session (undergraduate or graduate student, faculty advisor, invited professional) can answer questions and chime

Photo credit: Stephanie Vendetti.

Speakers on the Choosing a Graduate School panel respond to a question from the audience.

in with personal advice and experiences. This structure provides another avenue for mentoring across levels, including from one undergraduate student to another. Students are given tickets for the breakout session topics they choose while registering, but a popular ticket exchange program allows students to revise their choices as the conference progresses. Breakout sessions play an important role in community development by connecting small groups of students with similar interests who would not otherwise have met at a conference of over 200 attendees.

Networking

There are multiple networking opportunities built into conference activities as well as free time in the evenings. Every meal is a networking opportunity of some sort.

The conference organizers assign seats at the opening banquet to facilitate a broadening of interactions. Each table has a host from the university community and two or three visiting faculty members. The invited guests are distributed over different tables. Undergraduates are placed at one of these tables with other undergraduates from different schools. The overall effect is that each student has opportunities to interact with at least one more senior role model and several peers who they had not previously met. Some students might feel more comfortable sitting with their friends from home, but we avoid this to encourage students to make new contacts.

The second evening features an informal dinner event designed specifically for networking. Most tables are hosted by an invited professional or graduate student, and a few additional tables are set aside for networking among early career mathematicians or undergraduates. Participants choose a table to join for dinner and a second table for dessert, allowing each to pick two mentors of personal interest and to have a casual setting to get to know them and ask questions. Tables without hosts were added for the 2019 conference, and we were interested to see that undergraduates overwhelmingly prefer to sit with invited table hosts, whereas most of the early career attendees prefer networking with peers.

Attendees collect their own breakfast from a buffet line at the conference hotel and sit in self-selected groups. Occasionally these groups are based on mentor–mentee interaction, but more often they are groups of peers. By the time of the first breakfast on day two, students have already made some connections from the previous day and experienced the informality of the social climate; as a result we see very few students sitting alone. For the one unstructured lunch period that occurs during the conference, we assist in group formation by having a particular meeting location for anyone who is looking for a lunch group.

Funding

NCUWM was launched with funds that accompanied the UNL Department of Mathematics's Presidential Award for Engineering, Science, and Mathematics Mentoring and internal funds the Department was able to leverage based on this award. Since then the conference has been generously supported by NSF and the National Security Agency.

The impact of NCUWM and its future

While the primary purpose of NCUWM is to achieve a broad national impact by encouraging and facilitating undergraduate women to pursue and succeed in mathematical careers, its benefits reach beyond the undergraduate participants. The focus on vertical mentoring leads to professional development for the invited guests and improved mentoring skills for the visiting faculty who attend the conference. Moreover, many colleges and universities that send students to NCUWM require participants to report back to the other math majors at those schools about their experiences, thus providing a dissemination activity that allows NCUWM to impact a larger and more diverse group of students. A notable number of former NCUWM undergraduate participants are excited to return as invited graduate students or professionals, giving further anecdotal evidence of the value of NCUWM.

As part of formal assessments, respondents provided short responses to questions like "What was the most valuable aspect of NCUWM, and why?" We include selected answers from 2018 below, illustrating the influence of the NCUWM community and its mission on the participants.

> *[It was a revelation] To see that the thoughts, feelings, and experiences that I go through are not just me … I was validated, inspired, and given really great advice!*

> *I gained more courage to pursue a career as a female mathematician as I met others with the same goal.*

> *The opportunity for students to see more role models than they have available at their home institutions, as well as peers who share their interests in math [is the most valuable aspect. Having] a support system—even just knowing one exists for women in math—is crucial to persistence in studying math.*

> *Learning that many of my experiences as an underrepresented minority studying mathematics are shared by other underrepresented minority women who were able to have successful careers in mathematics was the most valuable and encouraging aspect.*

It's so hard to give only one answer. I'd have to say that the empowerment, inspiration, and the knowledge has for sure changed my life. There's no way I would have [obtained all of this] without this conference.

[I now know] there are a lot of people interested in math but also struggling—that I'm not alone.

The NCUWM organizing committee continually evaluates the effectiveness of the conference format and adjusts the program as needed in response to participant feedback and societal needs. This process has kept the conference fresh throughout its 20+ years. We have introduced new breakout topics such as "Careers with a Bachelor's Degree," "Being a Parent and a Graduate Student," and "Dealing with Microaggressions" as a result of participant suggestions or needs identified by the organizing committee. In response to the recognized benefit of community development, the conference schedule now includes more time for peer and mentor networking. Moreover, NCUWM continues to seek greater diversity in all aspects of its programming and processes.

Conclusion: The NCUWM Community

NCUWM offers an opportunity for participants to meet over 200 other women with common interests who would not likely have met under any other circumstances. The conference allows them to form connections with women with similar career aspirations. It provides a rich experience for participants to gain confidence, share their knowledge, and support one another. By forming friendships with peers, both undergraduates and early career professionals build support networks that help them maintain their motivation to pursue graduate study or become inspired to do so. The number of former NCUWM undergraduates who are excited to return as graduate students or invited guests testify to the success of the program.

As a 48-hour event, NCUWM can only go so far in helping women develop a sense of membership in the community of women mathematicians. One of our challenges is to find ways to extend the community-building role of the conference to the months and years after the attendees have gone home. We address this issue in part through a Facebook group, and we are now organizing reunions of NCUWM participants from all levels at national math meetings, beginning with the 2020 Joint Mathematics Meeting.

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6

The EDGE Community

Amy Oden and Ami Radunskaya[1]

In 1998, Rhonda Hughes and Sylvia Bozeman organized the first summer session of EDGE (Enhancing Diversity in Graduate Education) in order to support and mentor women in graduate programs in mathematics. Over the past twenty-two years, the EDGE community has grown to nearly 300 strong, made up of women at all stages of their careers, women who have chosen a range of life paths. Our wider community includes people of all genders, and we continue to evolve and grow through new partnerships. This chapter describes the EDGE community as it has evolved from my own perspective and how my involvement with EDGE has shaped my own professional life.

As a graduate student at Stanford, I watched as one of my new colleagues came out of the graduate director's office in tears. She had gone in a few minutes earlier to get advice on her courses: the topology class that she had signed up for seemed a bit over her head. His counsel? "Well, not everybody is cut out for graduate school." My friend didn't make it to the second year. Later, I found out that she was the recipient of a National Science Foundation Graduate Fellowship and was one of the top in her class at Bryn Mawr College. And yet, one sentence was enough to convince her that she didn't belong in mathematics.

Unfortunately, this story played as a refrain for many young, talented women starting graduate programs in mathematics. In the late 1990s, Bryn Mawr Professor Rhonda Hughes conferred with her friend and colleague at Spelman College, Professor Sylvia Bozeman. The pair, both professors at top women's colleges, had already collaborated on a successful program that encouraged undergraduate women to go to graduate school. But they were seeing these bright young women go off to graduate school in high spirits and leave before the first year was out. What could they do to help their students persist in their PhD programs? The result of their brainstorming was a summer program combined with intentional community-building and ongoing mentoring. They named it the EDGE (Enhancing Diversity in Graduate Education) program, with the aspiration that participation in the program would give their wonderful, talented students the "edge" that they needed. In 1998, the first EDGE summer program was held at Bryn Mawr College,

[1] This chapter reflects Ami Radunskaya's experience with EDGE, written with help from Amy Oden. These are Radunskaya's personal thoughts, and not necessarily the views of the EDGE Foundation.

with eight students. I was fortunate to be asked to teach real analysis that summer. That invitation changed my life.

That summer, I had more in mind than teaching real analysis. I also hoped to help foster a community for the EDGE participants and instructors. As an undergraduate, I had learned the value of studying collectively as a group when I worked as a peer mentor with UC Berkeley's Minority/Science Workshop Program. The workshops were developed by Uri Treisman in the late 1970s with the goal of building a community of first-year minority students that focused on achieving academic excellence and peer support. After studying various groups of students in first-year math classes, Treisman concluded that minority students tended to isolate themselves, not taking advantage of the support of their peers, depriving themselves of the academic and social benefits of working cooperatively in a group [3]. The workshops encouraged working together and sharing ideas—not just about mathematics, but also about how to navigate the academic waters. In the first five years of the program, Black and Chicano students who participated in the workshops enjoyed and excelled in their mathematics courses, as evidenced by lower attrition rates and higher grades. As a graduate student, I was able to implement Treisman's workshop model at Stanford: it was striking to see how a small effort at building a community of math students could pay off in terms of their success. Summer programs for women were built on the same concept of creating a supportive community, where mathematics was more fun because we were doing it together. Why not provide the collaborative aspects of Treisman's workshops with the ongoing support and camaraderie that the summer math programs provided for women?

EDGE's founders were both professors at women's colleges, one from a Historically Black College or University (HBCU) and one from a majority institution. In directing the program, Rhonda Hughes and Sylvia Bozeman kept a firm commitment to supporting women from diverse backgrounds, both in terms of educational background and in terms

Photo Credit: Ashlee Kalauli.

Tori Day, Berlinda Battista, Van Tran, Lynette Robinson, Ami Radunskaya, Alison Marr, Raegan Higgins, and Brandis Whitfield during post-banquet dancing, EDGE 2019 Reunion Conference.

of ethnic group. Like the Treisman model, part of the EDGE philosophy is that any woman who enjoys mathematics enough to succeed as an undergraduate major, and who has been recognized by professors and graduate programs as having the potential to succeed in a mathematics PhD program should, indeed, be able to flourish in such a program. A primary goal of the summer program is to provide women from diverse backgrounds the opportunity to become part of a supportive community, to expose them to the culture of graduate school, and to provide ongoing mentoring as they embark on their graduate studies. EDGE works towards this goal by first bringing together a diverse group of directors, faculty, and graduate mentors. I was fortunate to be among this group.

My first summer with EDGE in 1998 opened the door to relationships that have grown and matured over the last twenty years. As Jill Jordan (EDGE '99) has said, "There is something so special about making connections through a common interest in math. Following the example set by Sylvia and Rhonda, members of the EDGE community celebrate good times and help each other through difficult ones." Indeed, as a new faculty member, I cherished the time each year that I spent with EDGE directors. I made meaningful connections with other faculty and graduate students, many of whom have become friends and collaborators. I found that one of my personal goals aligned with another of the main goals of EDGE: to diversify the mathematics community. As I became more involved with the program, I also became more aware of the challenges that face us in achieving the goal of increasing diversity within the larger field of mathematics. Our smaller EDGE community supports its own members, but our dream is actually to change the whole. And this is why I continue to work with EDGE.

Communities are typically formed around shared ideas or common views. New participants in the EDGE program share a desire to earn a PhD in the mathematical sciences. The task of the directors is then to use this shared desire and the humanity in all of us to build and sustain a sense of community. For four weeks, the intensity of wrestling with problems together and articulating confusion and frustration as well as solutions, builds mutual trust. During the first two years of the summer program, we noticed that participants separated into small cliques, often along racial and socioeconomic lines. We realized that we needed help from non-mathematicians, so we introduced the Difficult Dialogues workshop. This three-hour seminar, led by a professional facilitator, is intended to foster an appreciation for each other's differences. Through guided discussions and activities, sometimes heated and fraught with emotion, this seminar encourages participants to go beyond their comfort zones in order to give and receive support from all of their peers. Other programmatic elements designed to intentionally build community include: shared meals in a space that encourages discussion, living and working together throughout the evenings without many other distractions, a "talent show" that celebrates differences, builds confidence, and raises cross-cultural awareness, and social events with EDGE faculty and directors so that we can get to know each other as complete human beings.

Concentric circles of community

The summer program's activities help that particular EDGE cohort, typically fourteen participants, become a tightly-knit group. In order to connect this small community to the larger EDGE community, we provide several levels of "connective support." In the middle

Photo Credit: EDGE 2003 Staff.

Patricia Pichardo performs, while Karoline Pershell acts as mic stand, and Hatsehpsitu Tull holds down the pages, EDGE 2003 talent show.

of the four-week summer program, the previous year's cohort of participants and mentors return for the Summer Symposium. This two-day event includes talks, panel discussions, and celebratory, social events. EDGErs at later stages in their careers give talks which highlight their research contributions, the continuing enjoyment in working in the mathematical sciences, and the journeys they took to get where they are. The previous year's cohort describes their first year—both the challenges and how they faced them—and fields questions from the group about to start their graduate program. Time is set aside for the EDGE directors to meet privately with the previous cohort, to hear about the highs and lows of the year, and to offer advice or plan interventions, if necessary. EDGE faculty have the opportunity to mentor each other and connect with graduate students. During the two days of the symposium, the new group of EDGE participants is introduced to the larger EDGE community, and returning EDGErs can reinforce their bonds.

After thirteen years of running the EDGE summer program, Sylvia and Rhonda restructured the EDGE leadership team. In 2011, Ulrica Wilson and I took over as co-directors of the summer program, so that Sylvia and Rhonda could concentrate on larger issues. Just as a family grows through generations, the EDGE community has grown its leadership generationally, with an intentionality in preserving the diversity of its leadership team. Faculty roles are generally filled by EDGErs in the professoriate, providing new EDGErs with a broader network of mentors that mirrors the diversity of their own cohort. This commitment to visible diversity is echoed in Keisha Cook's (EDGE '14 participant, '17 mentor) reflection: "Learning from successful women, especially women of color, was truly inspirational. Giving back to EDGE has allowed me to inspire others and provide support for future women mathematicians."

The "big reach" goal of EDGE is to create lasting change in the broader mathematics community, change that would result in a welcoming space for all to learn and grow as professional mathematicians and educators. In 2013, responding to overwhelming support from our community, we decided to incorporate: the EDGE Foundation was born! As the

years evolved, however, and we heard the same stories about graduate schools repeated by different cohorts, we realized that this kind of change is slow because it needs to happen at many levels. Government funding sources grew impatient, pointing out that programs such as ours had not "moved the needle." In response to both the funding pressure and the desire to make the broader community accountable for necessary change, EDGE has reshaped its funding structure. We now look for partnering institutions who will play an active role in hosting the summer program. Not only does this mean that host universities underwrite local costs such as housing and food for EDGE program participants, but it also implies the active involvement of the local community with the EDGE mission, or as I like to say, the experience EDGEifies them. Faculty, graduate students, staff, and other members of the host community are invited to attend colloquia and social events, encouraged to offer academic and personal support to EDGErs, and welcomed to strengthen their own networks through the EDGE Program. Through this deepened involvement, host communities forge a stronger connection with EDGE and our work, and persist as accountable partners in positive change.

Can we all be one community?

Over EDGE's twenty-two years, the world has seen a much needed shift in the way we advocate for women. While our initial impetus was to support and advocate for women graduate students in mathematics, we now are acutely aware of how different identities intersect to shape a student's narrative and experience. We have learned that in order to allow each student to show up authentically, EDGE must welcome differences. We must embrace that a Black student's experience is different from that of a White or Brown student. We must acknowledge that class barriers deeply affect a student's path through graduate institutions or the fact that homophobia and transphobia are still very present in academic spaces. The individual struggles and strengths that each EDGEr brings to the program need to be gratefully heard in order for us to provide actual support. However, I have struggled to find ways to honor difference in the urgency to create unity and family. How can we form a community based on math, humanity, and womanhood, when our worlds can otherwise feel so far apart? Borrowing from Dr. Christine Darden's "P to the 4th Power," I suggest that the inkling of an answer to this challenge lies in the three P's: perception, patience and persistence. We must continue to observe and reflect on the differences that each of us bring to our community; we must have the patience to work on understanding the impact of these differences; we need to persist in dismantling systemic cues that insist that difference is bad.

Virtual EDGE underscored the importance of intentional community-building

We faced another challenge in building community with our most recent summer program. Due to the COVID-19 pandemic, EDGE 2020 occurred virtually, through Zoom meetings, Google documents, online whiteboards, group texts, and video compilations. While I am very proud of the work that everyone put into achieving a virtual summer program, I know that we faced a number of additional challenges in building community,

and I noticed the strain wearing on the students. The EDGE participants are overwhelmed every summer—the courses are purposefully compact and intense, designed to encourage students to face their fears about graduate school. While we successfully created this challenging atmosphere during virtual EDGE, the support structures that are usually in place were harder to replicate. It was difficult for students to ask for help—after all, writing an email is scarier than lingering by the chalkboard after class. It was also more challenging to offer help, and I would struggle to find the right wording for each email. Absent the laughter, tears, and hugs that would happen naturally over a shared meal or in a late-night study session, we found navigating that personal space of insecurities awkward, sometimes painful, and ultimately unsatisfying. Nevertheless, I hope that we laid a foundation of trust. We will build on this foundation in the months and years to come, when hugs and tears can both be felt in person.

Virtual EDGE emphasized the need for intentionality in building community. The EDGE 2020 cohort—participants, mentors, and faculty—inspired me with their creativity and determination to form lasting bonds. EDGErs got to know details of each other's lives through an active group chat, and through endless zooming, they got to know and love each other's pets. The annual talent show was programmed into the Summer Symposium as a vehicle for the newest EDGE cohort to share talents beyond their mathematical prowess.

We were nervous about how effective this would be with participants physically isolated, spread across time zones, and with various access to technology. We should not have worried! What they produced was a beautifully crafted, hour-long compilation, complete with baking tutorials, musical performances, and satirical skits. A number of Black EDGErs shared powerful words about their fears and dreams in the wake of George Floyd's murder and the global response, and the whole cohort offered a collaborative poem discussing home, family, and identity. This video could not have been created without first building a reservoir of trust. We were reminded that even a virtual program cannot possibly exist as a bubble—there was no way to shut out the pandemic or a world that took to the streets to protest police brutality and racial injustice. In addition, participants had a window into families and households different from their own. Michelle Craddock Guinn (EDGE '04 participant, '08 mentor) has observed that "EDGE is more than a summer program, it is a family." While only time will tell what effect this unique summer program will have on their bond as a community, I am convinced that the EDGE 2020 cohort possesses the resilience and passion to succeed in their careers and will continue to be embraced by the EDGE family through and after the pandemic.

As the STEM community has increased its commitment to diversity, public recognition for the EDGE program has grown. In 2018, the EDGE Program was awarded the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM), the highest honor a mentoring organization in STEM can achieve. In 2007, EDGE was also named one of two Mathematics Programs that Make a Difference by the American Mathematical Society. I'm grateful that EDGE has received these acknowledgements and accolades and especially delighted that Sylvia Bozeman and Rhonda Hughes have garnered recognition for their work and achievements. I am more proud of the community of women I have been privileged to watch blossom because of EDGE. EDGE has supported over 180 women in earning their PhDs and master's degrees, with many more young women currently working towards their degrees. I see EDGErs throughout

Image courtesy of Victoria Robinson.

The EDGE 2020 cohort, illustrated by Victoria Robinson (EDGE '19).

the community now as leaders and teachers. In fact, over 100 EDGE alumnae are teaching the next generation of mathematicians!

EDGE 2010 participant Yen Duong shared that she finds herself "organizing women in math conferences, writing and talking about being a woman and mother in math, and mentoring any women and girl students I run into, all because of EDGE," and I can testify that many of our participants approach the math community with this intention. In fact, EDGE has expanded to include much more than the Summer Program, through numerous initiatives led by our alumnae. Since 2013, EDGErs have regularly organized sessions at national meetings, where they give talks on current research and professional projects, promoting the visibility of women from a variety of backgrounds in our mathematics community. In 2016, EDGErs Candice Price, Raegan Higgins, Erica Walker, and Shelby Wilson formed the website Mathematically Gifted & Black, which celebrates the lives and works of Black mathematicians each Black History Month. In 2020, EDGE became a fiscal sponsor for Mathematically Gifted & Black, and supports the organization with financial oversight and other bureaucratic burdens. In 2019, members of the EDGE community submitted essays and research papers to comprise *A Celebration of the EDGE Program's Impact on the Mathematics Community and Beyond* [2]. The book showcases the academic work of EDGErs, while honoring the EDGE ethos and personal importance. All developed by EDGE alumnae, these projects offer the same community and professional support that make the EDGE program so invaluable.

The EDGE organization continues to grow. In 2019, Abel Prize winner Karen Uhlenbeck gave a substantial part of her prize money to the EDGE Foundation to establish the Karen EDGE Fellowship Program. The Fellowship is intended to support and

enhance the work of mid-career mathematicians who are members of an underrepresented minority group. In May of this year, we announced our inaugural class of Karen EDGE Fellows: Pamela Harris, Mohamed Omar, and Bobby Wilson. I am proud that the EDGE organization supports these three brilliant educators and researchers and look forward to the change they will make.

What started as a program with the specific aim of supporting women through the first year of their PhD program has grown into a web of action, a network of successes. Our EDGE community members are not only successful in traditional academic careers, serving as Department Chairs, Deans, and Provosts, but they are also taking on roles in government, industry, and education. EDGErs are advising state governments on K-12 education, developing math curricula, organizing events on Capitol Hill, and serving as AAAS Fellows. They are building a wide range of outreach initiatives, including leading Math Circles, hosting Sonia Kovalevskya Days, and organizing and participating in conferences and workshops aimed at broadening participation in the mathematical sciences.

This reflection on the EDGE community has been something of a personal revisit of my own path. When I met Rhonda and Sylvia in 1998, I had no idea that we would braid our lives together over the following decades, that we would share so many joys, tears, fears, and fulfillment. Through EDGE I have met many of my closest friends and my greatest inspirations. I've danced and played at EDGE weddings, held EDGEr babies, and celebrated after EDGE PhD defenses. When I've needed advice, ideas, or just a giant dose of hope, I turn to EDGErs. And I believe that I am not alone. I am proud of the many accomplishments of EDGErs over the years, but I am bursting with pride in the community that we have built and continue to build. In typical fashion, I turn to an EDGEr for help in articulating my own thoughts and feelings:

> *Through EDGE, I belong to an amazing and diverse community of women mathematicians that has invigorated me throughout the various stages of my career. EDGE has instilled within me a confidence in what I can accomplish; shown me the importance of doing good work and being active in my discipline; provided financial support and various professional opportunities; given me role models like none other; made me deeply grateful for the exceptional mentoring I have received along the way; and, inspired me to extend the mentoring to those who come after me. Basically, EDGE is the gift that keeps on giving.*
>
> —Erica Graham (EDGE '06 participant, '10 mentor, '19–20 instructor)

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7

Prepare2Nspire

Effects of a Near-Peer Tutoring Program

Elena A. Contreras Gullickson
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Everyone has a deep desire for connection and a need for belonging. Fortifying these deep human needs has become a wonderful yet unintended consequence of the mathematics learning community Prepare2Nspire (P2N). The original goals of P2N were (1) to build mathematics confidence, connections, and content for underrepresented youth through cascading tutoring and mentoring, and (2) to develop a Science, Technology, Engineering, and Mathematics (STEM) pipeline to higher education. Now, in its seventh year of programming, many other unintentional benefits and outcomes have emerged including academic competence, stronger communication skills, cultural support, and a sense of community. This chapter examines these outcomes, with specific attention to the process of building and strengthening communities. Using participants' voices as evidence, it offers a description of the program, its setup, challenges, and outcomes.

Program rationale

Algebra is a gatekeeper course for scholars to have access to high-quality STEM education [5]. Consequently, in 2011 the state of Minnesota set a mandate for every student to successfully complete algebra by grade eight. Despite the admirable intentions, this legislation included neither resources to complement this mandate nor training for teachers who would be responsible for these courses. It also did not consider the skills and abilities of students who were to learn algebra in eighth grade (especially urban learners who were historically behind on all accountability measures). In particular, this legislation further marginalized students of color, English language learners, and low socioeconomic status students who were already struggling to achieve in mathematics. In fact, Minnesota has one of the widest racialized achievement gaps in the United States [6]. One of the greatest setbacks for students from low-income families and marginalized communities is access, both economic and educational [5].

With all of this information in mind, the program founder, Dr. Lesa Covington Clarkson (co-author), attended community events to network and meet with leaders about an idea she had sketched on a napkin that would help urban public school students learn mathematics. The leaders would respond encouragingly yet take no action. Thus, she wrote a grant to fund and create a tutoring program that would support the new mandate, equalize access, and create a diverse pipeline to STEM higher education. The result was the inception of Prepare2Nspire. The program recently finished its seventh year and has influenced the mathematical journeys of over 500 participants. Some descriptions of P2N by eleventh grade participants, Queen, Zara, and April, respectively, include:

> *It's a place that helps you with your homework, helps you study, learn how to do math. It's a place where you can socialize with other people. They also help you with the ACT.*

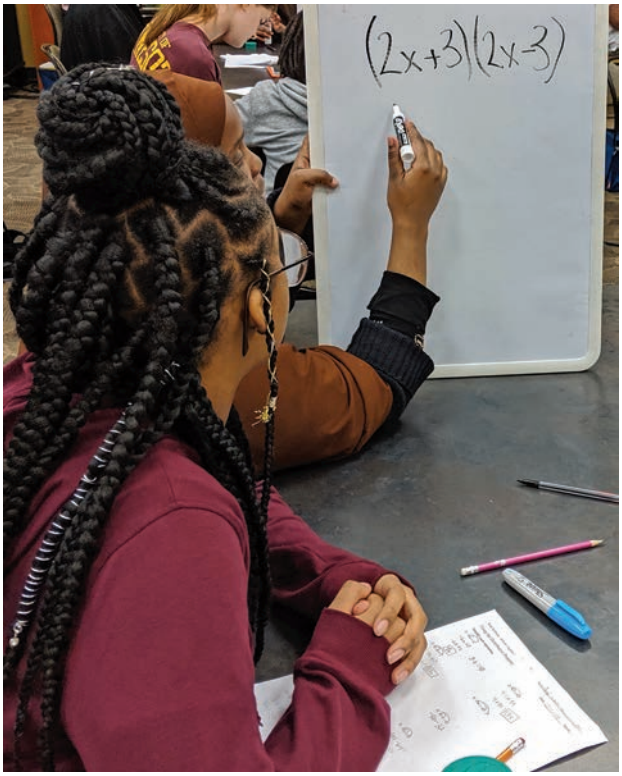
> *A place where everyone is welcome and respected and a place where students come to learn from their tutors but also their peers. It's a very homey feeling. No one's like awkward or anything. They treat you like a person they respect and they do respect us and they do care for us and so it feels like you're at home just doing homework.*

> *A lot of diverse people. A lot of people from different schools and different backgrounds.*

Program structure

Prepare2Nspire is a vertically-integrated tutoring and mentoring program primarily for underrepresented mathematics scholars in grades eight and eleven. The grade levels were intentionally selected because of the algebra-centric courses required of students at this point in their mathematical training and the high-stakes testing that occurs during these years. For both groups of students this includes state-mandated assessments and for eleventh graders this also includes college admission testing. There are many intricate components of this near-peer tutoring program. Some important elements of P2N include ACT test preparation, tutoring, and mealtime. Each of these components plays an essential role in creating a sense of belonging for participants.

The unique configuration of this program encourages community building. A university undergraduate student usually majoring in a STEM discipline (e.g., mechanical engineering or biology) joins with four eleventh grade students and four eighth grade students to form a learning community. The number of learning communities varies from year-to-year and is dependent upon the amount of funding available for the program. The greatest number of communities in a year was thirteen (about 100 participants) and the fewest number of communities in a year was nine (about 60 participants). As Desiree, an eighth grader, describes it, "P2N communities are supportive. They show you that they care." The learning communities, seated at a single table, are named after underrepresented STEM professionals such as Katherine Johnson, known for her computation work for NASA, and Alexa Canady, the first African-American neurosurgeon. Naming the communities in such a way purposefully allows students to view themselves as potential STEM professionals. The undergraduate and eleventh graders serve as mentutors (mentor + tutor) because they are both mentors and tutors to their younger peers. The mentutors provide formal mathematics tutoring to the participants while also engaging in informal conversations that bolster personal growth.



Prepare2Nspire scholars working on a problem.

The confluence of mentoring and tutoring in this important relationship establishes trust which, as Brené Brown [2] describes, is built in small moments over time.

The opportunity for students to serve as leaders in their learning community also instills a sense of belonging and builds confidence [4]. The security students feel in their communities strengthens their academic abilities and allows them to take academic risks. They ask more questions and they persevere in ways they might not have done otherwise. Queen, an eleventh grade participant, says,

> *Before coming here, if I didn't understand math, I just didn't do it all. When I came here, I found help that I could get. I realized that I could understand how to do it instead of just leaving it to the side.*

Queen's insights capture the power of the program to build confidence and reframe a participant's attitude towards mathematics.

This cascading tutoring and mentoring model benefits all program participants. As Zara, an eleventh grader, reflects, "But then I came here, and it's easy for me to learn here, and there's a bunch of people helping me instead of, like, just one teacher. It's like every student helps each other." A typical P2N session begins with an hour of tutoring of eighth graders by the eleventh grade participants and undergraduate tutors. Desiree, an eighth grade participant, observes, "When I was doing my work they would ask me if I needed help or if something was wrong." Eighth graders get individualized attention while the

mentutors revisit previous mathematical concepts. Revisiting these concepts as tutors helps to deeply ingrain the academic content so that it is easily accessible when needed for their own coursework and standardized tests.

The meal served after the first hour of tutoring forms an integral part of the program. Eating a meal together while engaging in conversation is a strong community-builder. Participants laugh, talk and share their thoughts and ideas in an informal setting. As Tanisha, an eighth grade participant, describes, "… [in] smaller groups, you get individual help. You can talk more at P2N even if it's not about math." Meal time has a family-oriented feel to it. It is another way to establish trust between mentutees and mentutors. Authentic mentoring occurs during this time as participants ask their mentutors open-ended questions that help to validate their current status. For example, Roxanne, an undergraduate mentutor, was asked two questions during one of the evening meals: "Have you ever cheated on a test?" and "Have you ever fought?" Roxanne's honest answers to these questions invited scholars to share their own struggles with cheating and/or fighting so that they could have productive conversation around these types of choices. It also speaks to Brown's [1] assertion that true belonging occurs when we show up as our authentic yet imperfect selves. When mentutors present themselves as scholars who have made mistakes, their mentutees can relate to them better and envision themselves as successful in spite of any mistakes they may have made. After the meal, the eighth grade students depart, and the eleventh grade participants become the focus of the next ninety minutes.

These scholars, high school juniors, are preparing for life beyond high school and, in particular, for high stakes assessments like the ACT and/or SAT tests during this academic year. Their success on these tests determines not only their college entrance acceptance possibilities but also the type of institution they can attend. As such, standardized test preparation forms an integral component of P2N alongside homework help. Participants take a practice ACT mathematics test in the fall and again in the spring. They are supported in ACT test preparation every week with mini content lessons. Zara documents the benefit of this part of the program when she notes, "They gave me advice on how to take ACTs. I learned better how to approach a math problem and solve it. Before this program I had no idea what the ACT test would look like." P2N participants have averaged a three-point increase in their practice ACT exam scores from fall to spring.

There is a notable outlier to this statistic. As a high school junior, Maria participated in P2N and her ACT practice test score increased five points. Maria gained tutoring skills and increased confidence at P2N; she then enrolled at the University of Minnesota and is pursuing a degree in mathematics. She also chose to serve as a P2N undergraduate mentutor. Her unique experience and historical perspective as a mentutee and mentutor allow her to provide support and encouragement in positive ways. For example, Maria is a Spanish speaker. During her first year as an undergraduate mentutor, several participants were Spanish speakers and one participant spoke very little English. Maria translated several mathematics topics and tutoring conversations for the students and was able to fill a previously unmet need in the program. When Maria took her first mathematics course at the university, she struggled. Using the idea of the learning community she had gained at P2N, she formed a study group with her fellow undergraduate mentutors that would meet

after the eleventh grade participants went home. She demonstrated the benefits of asking for help and building community.

Many P2N participants come from marginalized communities. Susannah describes the community at P2N as, "it's like full of people my age, mostly people of color too so … I don't think anybody feels discriminated—pretty much it's all types of people." Some students face multiple forms of marginalization. Zara, who identifies as being Black and Muslim, describes what that intersectionality can feel like in her community.

> *I am treated differently because I am also a Muslim. I feel like there are different versions of Black. And then living where I do live, it's just the way you are perceived. Like people pity you, I believe. So it's like oh my gosh you've been through that and it's like no, it's just an obstacle I have faced.*

Zara is intentional about finding true connections with others so that they see and relate to her beyond the color of her skin and the scarf she wears.

There are a variety of potential obstacles that could prevent a student from participating in the program. Consequently, the program is designed to support participants' attendance despite these barriers. For example, if a participant is responsible for sibling childcare, they are allowed to bring their school-age sibling to tutoring and the sibling can also receive mathematics tutoring. Students with transportation needs receive city bus passes so they can travel to and from the program site. Students are given high-quality school supplies including notebooks, pencils, rulers, grid paper, folders, and a handheld graphing calculator complete with training on its use. Students can use the graphing calculator on ACT and SAT tests, further tightening gaps in resources students may have.

Program challenges

As Zara observes, "You should face obstacles, everything shouldn't just be perfect. I feel like obstacles make you who you are and then you learn from them." While she was referring to the study of mathematics, this sentiment holds true in many areas in life including implementing and sustaining a learning community such as P2N. For example, at the beginning, the program met twice a week, a weeknight and Saturday morning. Although participants benefitted from having access to mathematics assistance more than once a week, their other responsibilities and activities often led to attendance issues. P2N now consistently meets on Wednesday afternoons from 4:30–7:30 PM. Families and community members familiar with the program now encourage other students and families to participate.

Initial funding came from an institution focused on creating a pathway to higher education. Their grant came with demands that influenced program design and vision. In particular, they required participants to enroll in P2N for both eleventh and twelfth grades with the hope of influencing their choice for higher education. The investment in the program for students in grade twelve was very different from that of students in grade eleven. In particular, the academic environment required to prepare eleventh graders for high stakes testing conflicted with the shifting focus of twelfth grade students towards a "senior slide." The varied attitudes in participants made for some difficulties in maintaining program structure. This requirement also limited the number of eighth graders who could

attend the program. This caused an imbalance in the critical one-on-one mentutoring between eighth and eleventh graders. This early experience underscored the importance of maintaining program integrity even when it comes at the cost of financial support.

Funding a holistic program with wrap-around services is costly. While P2N started with a large multi-year grant, private donations supported the later years of the program. Program organizers invest considerable energy into procuring funds for each year. The meaningful outcomes for students and the positive impact to the broader community testify to the importance of sustaining the program. The intangible benefits at P2N include creating a welcoming community that supports students not only academically but also personally throughout their year. The program also bolsters confidence in students' mathematical and test-taking abilities. Since these outcomes are difficult to quantify, however, they can be an obstacle rather than a source for the procurement of funds.

A final challenge this community faces is that the undergraduate mentutors are students themselves. They have exams, illnesses, and other commitments that can affect their attendance. Since relationships form the foundation of the community, this can become an issue for mentutees. They arrive ready to reconnect with their mentutor, share about their week, and work on mathematics. The mentutees are visibly disappointed when their mentutor is unable to attend a P2N session and their engagement level decreases for that week. The challenges remind us to foster creative problem solving skills and to help participants to grow in their adaptability.

Program outcomes

In order for P2N to accomplish its mission(s), it pushes back against deficit narratives students might possess as a consequence of their racial or economic status or positioning at school [3]. Former first lady Michelle Obama [7] shared this ideal when she described her work with young girls in her memoir *Becoming*. "No story is simple," Obama asserts,

> *But I was there to push back against the old and damning narrative about being a black urban kid in America, the one that foretold failure and then hastened its arrival. If I could point out those students' strengths and give them some glimpse of a way forward, then I would always do it. It was a small difference I could make (p. 388).*

Like Michelle Obama, P2N strives to make a strong difference in the lives of the participants and their post-secondary trajectories by showing the possibility of success. Through individual and collaborative groupings, P2N allows students to embrace their unique learning styles and approaches to learning. Perry, Steele, and Hilliard [8] argue that "… excellence (not simply adequacy) is in full reach of the masses of African American (and by extension other minority) students, yet many students are not supported to reach this potential for excellence." P2N is a community that supports students in reaching their mathematical potential. Along the way, the program also promotes a sense of belonging in a community, increased confidence, and strengthened content knowledge.

There is something powerful about walking into a room filled with people who look like you doing mathematics. It builds you up in a way that makes you feel accepted, and makes you feel like a valued member of that community. This critical feeling was conveyed by Janelle when asked about her experiences at P2N. She responded that,

> *When I walked into the room, I knew that I belonged. It's a place where you can feel safe. Where you can talk to people and not be scared of whether you will be accepted or not. Where you can pretty much be yourself.*

Janelle's description is that of true belonging; you know you are surrounded by people who are there to support you and build you up while holding you accountable to learning mathematics. This acceptance and accountability is a common theme felt by participants. Desiree described this as "It's different 'cause there's undergrads there. They help you with your math and you just get a different vibe 'cause people at P2N aren't judgmental."

When participants can truly be their authentic selves, then they can focus on mathematics. This allows students to become confident learners while increasing their academic competence. These two outcomes are interconnected. As students gain confidence, they are more willing to explore difficult mathematics. Their success is manifested in higher test scores, increased participation in their math classes, and greater communication skills. As students experience these positive changes in their academic performance, they become more and more confident. As Tanisha describes,

> *Before P2N, I was hesitant about learning more about math and me teaching it to others, but after my participation, I was more confident about teaching math to others in different ways and this program made math more appealing to me.*

The collaborative nature of the learning communities shows students that mathematics does not need to be done in isolation. They begin to recognize, as Queen observes, that they can initiate collaboration, "like if you know something and the person is waiting for someone else to help them, just like go up and help them." This is what community does, they notice and they show up. This is a nuance that cannot always occur in formal classroom spaces. The expectations for leadership and mentutoring at P2N help sustain an environment where everyone can thrive. The P2N model creates the space for learning mathematics and the participants make it happen. As Susannah describes,

> *I feel like since we mentor younger kids than us … I'm not really that old since I'm a junior and they're eighth graders but I've seen more academic-wise. I feel like the way*

Prepare2Nspire scholars in their study space.

> *I teach them is different from the way I would teach like someone who is my age. You don't know if they are struggling or not so you can't just assume that they're going to get it like that [snaps fingers] the way you do. So, I take precautions as to find out what they're struggling with and then go from there. I don't just say, "oh no it's easy" 'cause I hate it when people do that. It's just… you don't know it's easy. It's easy for you but not for me.*

Susannah's reflection is a reminder of how troubling the use of the phrase "it's easy" can be to students in mathematics courses when they are struggling to grasp concepts and build knowledge.

Participants can take the critical outcomes of the program with them throughout their lives. The turning points they experience such as "I started to read problems more carefully," "I feel like I regained back my confidence in math and my love for math this year," or "My test scores are higher again," become life skills that affect their trajectory for future times of struggle. During their time at P2N, they learn how to ask for help and they see their mentutors ask for help. They realize that they are not alone in their struggles. They recognize that they can accomplish challenging tasks; it may take perseverance and hard work, but it's worth it for the reward of success. As Janelle describes it,

> *I feel like for you to be successful in anything, you have to put in effort. And for you to get something out of it, you can't just be like, "I wanna do this." You have to give your time and give your work ethic.*

In realizing this, the trajectory toward STEM higher education feels more attainable. Participants see undergraduates who look like them pursuing STEM degrees including mechanical engineering, mathematics, and biology. They have a relationship with a STEM professional who shows them that she cares for them. As April articulates,

> *I mean, it does motivate you because [program director] paved quite a bit of way. She has a PhD, she pretty much broke stereotypes. Most people think a man would do that or you don't see many women who have PhDs. It's mostly men.*

P2N aims to help students develop their sense of self to the point where they can reframe existing structures and include the potential of a STEM profession. Eighth grader Desiree now describes her career trajectory "I wanna be a doctor. Or surgeon. Or OB/Gyn, but I also want to be an activist. But I love taking pictures so I'm also thinking about being a photographer." Desiree may change her mind again and again about what she wants to do, but the potential to pursue a STEM career exists. Her range of choices points to the success of P2N.

Conclusion

In encouraging a friend to participate in P2N, eighth grader Renae asserts, "I think you should go to P2N because, ya know, you might meet your lifetime friends there and express your feelings to someone if you don't feel that type of feeling at home." Her powerful description shows that she feels part of the community at P2N. She recognizes the strong relationships she has developed and intends to maintain. She also calls attention to the open communication and vulnerability that P2N creates. She is not alone in feeling like

this. Eleventh grader, April admits,

> *I used to guess on my math homework. Most of the time, I didn't even do it. I also slept in class, but the day I came here, I started taking math seriously and I completed my homework and when I was stuck I would ask for help. I am happy to say P2N changed my life.*

This is year seven of P2N programming. Our hope is that participants experience lasting effects. The first cohort of eighth graders is potentially in the first year of college while the first group of eleventh graders are potentially graduating from college. Our current research goals include looking at how P2N may have influenced participants' academic decisions. This entails examining which STEM courses participants take, whether they enroll in post-secondary education, their choice of undergraduate majors, and the types of careers they hope to pursue.

P2N helps create a space that pushes back against the despair and fear often associated with mathematics and replaces it with positive mindsets. Each week when students go home, everybody says, in unison, "Math is hard. So is life. We accept the challenge!" That notion not only becomes a part of their mathematics journey, it becomes a part of their life journey.

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8

Bryn Mawr College, 1885–1940
"mathematics on its mind"

Madeline E. Polhill

Examining the past as inspiration for the present

Women and underrepresented racial and ethnic groups constituted only 30% and 9%, respectively, of full-time graduate students pursuing doctorates in mathematics in 2017 [3]. Despite ongoing initiatives to encourage and advance underrepresented groups in mathematics, these discrepancies continue to exist. To offer insight into how to address this pressing contemporary issue, this chapter examines one historical community that successfully advanced women in mathematics with an eye towards identifying tried and true strategies that have no expiration date.

Prevalent attitudes during the final years of the nineteenth century suggested that women, as the supposed weaker sex, would naturally fail in mathematics and should thus devote themselves to domestic duties. Some women interested in mathematics, however, were able to make their voices heard during this period [9]. In 1886, Winifred Edgerton of Columbia University earned the first mathematics PhD awarded to a woman in the United States, and 228 women followed by 1940 [4]. During these years, women found an increasing number of opportunities to fulfill their dreams of pursuing advanced mathematics.

Few institutions better revealed the flourishing of women studying mathematics during this period than Bryn Mawr College, a school which, according to a 1929 review, had "mathematics on its mind" [2].[1] Founded in 1885 as a Quaker school near Philadelphia, Pennsylvania, Bryn Mawr was the only women's college in the United States to support a doctoral program from the outset [12]. As science historian Margaret Rossiter explained, "Mathematics was distinguished at Bryn Mawr, but of little note" at the other women's colleges [13]. Despite the small size of its mathematics program, Bryn Mawr awarded nineteen mathematics PhDs to women prior to 1940, bested only by Cornell University and the University of Chicago [4]. This success was largely thanks to four strong women.

[1] This quote appears within the larger context of a statement suggesting that, despite the school's unique focus on mathematics, few students chose to "specialize" in the subject [2]. Those who did study mathematics, however, helped create a robust community.

Photo Credit: Bryn Mawr Special Collections, Date: 1886, Collection: Bryn Mawr College Photo Archives, Identifier: PAE_CPOS_002_BMC_f.jpg

Bryn Mawr College Class of 1889. This image features M. Carey Thomas (seated) and Charlotte Angas Scott (standing) at the left edge of the doorframe.

Between 1885–1940, administrators Martha Carey Thomas and Marion Edwards Park and mathematicians Charlotte Angas Scott and Anna Pell Wheeler cultivated mathematical excellence at Bryn Mawr College.[2] An exploration of the enduring legacies of these four women helps identify potentially successful strategies with timeless possibilities for supporting underrepresented groups in mathematics and creating successful mathematical communities today.

Designing physical spaces

These women recognized the importance of physical spaces in creating a scholarly community particularly supportive of female scholars. M. Carey Thomas, President of Bryn Mawr from 1894–1922, prioritized physical spaces that reflected the value of academic pursuits, just like the buildings at men's colleges [6, 12]. As her biographer described it, "[a]s the visible sign that truth had no sex, the Bryn Mawr campus gave no clue as to the gender of its student body" [6]. This commitment translated to the formation of spaces that promoted wholly intellectual activities. Specifically, Thomas drew inspiration from the seminar model of the Johns Hopkins University, where each graduate department had its own seminar room with advisors' offices in close proximity. In this model, well-equipped seminar rooms offered access to research materials and provided a space for students and faculty members to share ideas and offer support for each other's research [6].

[2] Though a lengthy consideration of her legacy is outside the scope of this chapter, Thomas helped ensure these efforts extended almost exclusively to white Christian women during the school's early years.

Across Bryn Mawr's campus, scholars had access to the most exceptional study spaces. The library's light-filled, lavishly-decorated reading room featured 136 desks that encouraged women to focus on their work. Thomas also wanted each student to have a study separate from her bedroom to support personal academic needs [2]. M. Carey Thomas explicitly provided female scholars with an environment that not only encouraged women's intellectual activities, but also promoted a sense of belonging by reflecting the idea that, as a women's college designed to support academic endeavors, the school had been intentionally created with female scholars in mind.

This commitment to creating effective and welcoming workspaces applied to the mathematics department specifically. Charlotte Angas Scott, head of Bryn Mawr's mathematics department from 1885–1924, and Anna Pell Wheeler, head of the department from 1924–1948, provided the members of their community with spaces conducive to scholarly work [12]. Scott and Pell Wheeler proved instrumental in developing a sizable mathematics library that ultimately competed with all but those in the largest institutions [1, 7]. Pell Wheeler herself served as a valuable source for mathematical texts, as well. She offered students her own books, even when she still needed them, to guarantee that they could always access relevant reference materials. Pell Wheeler also invited graduate students to her Adirondacks summer home—aptly called "Q.E.D.," where she created an environment conducive to research productivity [5]. These women recognized the importance of physical spaces favorable to intellectual pursuits, and they strove to support their community in this way.

Photo Credit: Bryn Mawr Special Collections, Creator: Broadbent Company, Date: 1890s/ Date created: ca. 1895, Collection: The Albert M. Greenfield Digital Center for the History of Women's Education.

Bryn Mawr College dorm room.

Creating connections

Thoughtfully-designed spaces physically encouraged productivity in one way. Collaborating with others advanced members of the community in another. During the 1896–1897 school year, Charlotte Scott and James Harkness founded the Bryn Mawr College Mathematics Club. The club helped provide faculty members, graduate students, and women who had recently earned their graduate degrees with the official opportunity to collaborate [4, 12]. As reported in its records, the club allowed scholars to study and report on new work in mathematics, share research they had conducted themselves, and learn about the mathematical pursuits of other scholars at Bryn Mawr [9, 12]. These activities helped women expand their mathematical knowledge beyond what they had learned in their courses and gain an appreciation of the collaborative research process. A department highlight for many decades, the club allowed for the sharing of ideas crucial to developing new mathematics [12]. In this sense, Scott helped create a community where young mathematicians and established faculty members alike could grow in their mathematical understanding and sharpen their research skills.

This commitment to cooperation extended into the 1930s. Marion Edwards Park, President of Bryn Mawr from 1922–1942, developed institutional connections that continued to expand the community's academic options. Park was instrumental in establishing a collaboration between Bryn Mawr, Haverford College, Swarthmore College, and the University of Pennsylvania. Beginning with the 1933–1934 school year, the schools' libraries coordinated on purchases and checkouts, students took classes at the other institutions, and professors taught courses at the other schools [11]. During the partnership's first year of existence, students and professors in Bryn Mawr's mathematics department collaborated with their colleagues at the University of Pennsylvania on two courses, one on linear functional equations and one on number theory [12]. By forming this connection, Park created opportunities for students and faculty members in Bryn Mawr's mathematics department to gain access to enhanced resources and learn a greater variety of mathematics than would have been possible with their own resources alone.

Building off Park's initiatives, Anna Pell Wheeler formed a Mathematical Club with these three schools during the 1937–1938 school year. The faculty members and graduate students from the four schools who attended could reap the benefits of collaborative mathematical endeavors and gain insight from individuals with whom they might not have crossed paths otherwise. Pell Wheeler also maintained connections with mathematicians at Princeton University and the Institute for Advanced Study, taking her students to Princeton to listen to and meet with Hermann Weyl, John von Neumann, and Albert Einstein [1]. These experiences enabled Pell Wheeler's students to learn directly from some of the most exceptional scientific scholars of the era and of all time. By exposing her students to such a wealth of mathematical ideas and personalities, Pell Wheeler prepared her students to participate in the broader mathematical community. Out of an understanding that building a productive community requires working together, Pell Wheeler and her Bryn Mawr colleagues modeled collaboration and its possibilities for their students.

Leading the way

But Bryn Mawr's mathematics department owed its success to more than effective strategies. The lives and legacies of the women who guided this community during these productive years offer arguably the most vital clue to the department's achievements. In particular, the examples of Charlotte Angas Scott and Anna Pell Wheeler call attention to the power of inspirational leaders to guide other members of their communities to greatness.

Scott led the way for her mathematics students by breaking barriers during her exceptionally successful mathematical career. Her more than thirty mathematical publications included *An Introductory Account of Certain Modern Ideas and Methods in Plane Analytical Geometry*, a book so popular it was reissued thirty years after its 1894 publication [8]. Scott's successful research career prompted the preliminary edition of *American Men of Science* to rank her thirteenth among all American mathematicians (despite the fact that she was not a man) [4]. She also served as the first woman on the original Council of the American Mathematical Society (AMS) and, beginning in 1905, as its only female Vice President until 1976 [4, 8]. Scott's exceptional mathematical career proved to her students and colleagues the possibilities available for women in the field, which helped establish a community fully aware of women's mathematical potential. By boldly entering into spaces previously occupied only by men, Charlotte Scott made room for members of her own mathematical community at Bryn Mawr to participate more fully in mathematics.

Scott's leadership extended to her teaching. Throughout her career, Scott maintained a captivating teaching style that inspired all levels of students, from the weakest to the brightest. As her graduate student Isabel Maddison asserted, "Professor Scott … has the rare gift of lucid explanation combined with an intuitive perception of just what the student could grasp so that she never bored by being too easy or discouraged by being too difficult. Nor did she spare any effort to help a stupid student who really tried" [7]. Regardless of their mathematical abilities, Scott knew exactly how to reach individual students. Apparently, Scott understood how to encourage even the most inexperienced students to begin solving mathematical problems [10]. But she could also impress the sharpest students with the beauty of mathematics in her breathtaking lectures. Capturing the attention of dedicated students of all abilities, Scott helped build community at Bryn Mawr by creating a supportive mathematical environment where motivated students could find the inspiration to excel.

In addition to encouraging young mathematicians in their studies, Scott guided students with her thoughtful insights. Isabel Maddison revealed Scott's astute abilities as a mentor, claiming that Scott "was appealed to for help in all kinds of difficulties. Her keen logical mind was brought to bear on any subject, no matter how far from her real interests, if it seemed of importance to anyone, and the way in which she dragged the relevant facts to light, analyzed them and deduced the solution, was an object lesson in judicial reasoning" [10]. Students recognized Scott's ability to sort through a problem carefully, and they reaped the benefits of this skill in the form of thoughtful advice. Scott's life shows that mentorship beyond traditional duties helps provide the support many members of the mathematical community need to thrive.

During her own career at Bryn Mawr, Anna Pell Wheeler developed a similar legacy of building community through inspirational leadership. Like Charlotte Scott, Pell Wheeler helped create a welcoming space for female mathematics students and colleagues by leading by example. Green and LaDuke consider Pell Wheeler one of the most significant mathematical contributors, particularly in pure mathematics, among the members of their study on women in the American mathematical community who earned PhDs prior to 1940 [4]. (Scott was only excluded from consideration because she was born and educated abroad [4, 8].) Among other honors, Pell Wheeler earned a star in *American Men of Science* in 1921 and became the first woman to give an AMS invited address in 1923 and the first woman to deliver the AMS colloquium lectures in 1927. By realizing such impressive accomplishments in her own mathematical career, Pell Wheeler demonstrated to her students and colleagues the wide variety of opportunities available to female mathematicians and paved the way for them to follow in her footsteps. Like that of Charlotte Scott, her example suggests the importance of role models in developing communities where all members believe in their own power to succeed.

Pell Wheeler also cultivated a reputation as an exceptional educator who spread her passion for mathematics to her students. Mrs. Wheeler, as her students called her, advised eight female PhD candidates, more than any other woman in Green and LaDuke's study [4, 14]. She demonstrated the utmost dedication to ensuring her students' success in and fascination with mathematics. Former student Vera Ames Widder wrote to Pell Wheeler, for example, "I was deeply impressed in your interest in your students and even more by your feeling for mathematics" [5]. Driven by her own passion for the subject, Pell Wheeler dedicated her teaching career to creating a supportive academic environment where students would learn wholeheartedly to love mathematics. Her legacy provides insight into the power of enthusiastic leadership to transform groups of individuals into thriv-

Photo Credit: Bryn Mawr Special Collections, Date: unclear, although likely 1904, Collection: Bryn Mawr College Photo Archives, Identifier: PAB_Taylor_019_BMC_f.jpg.

Three students in Math Library, Taylor Hall.

ing communities of people deeply invested in the community's purpose—in this case, to pursue mathematical excellence.

Pell Wheeler also remained mindful of the personal needs of her students, recognizing that mental wellbeing would help these members of her community succeed. Former graduate student Ruth Stouffer McKee recalled of Mrs. Wheeler, "She recognized that we needed help in our emotional and philosophical growth. She encouraged us to come for tea, to just drop in. She was a good listener. I don't know how she did it, but before you knew it you had told her all sorts of things which you had never intended to tell her." By creating such an open atmosphere where students could comfortably discuss their concerns, Pell Wheeler effectively acted as a mother figure to her students, treating them like the children she never had. So dedicated in her role as a mentor was Pell Wheeler that she maintained contact with her former students even after her retirement [5]. With such a devoted ally as Mrs. Wheeler, the Bryn Mawr mathematics cohort of the Anna Pell Wheeler era could proceed confidently into the future, knowing their mentor would be available to encourage these women as long as she lived.

Throughout her time at Bryn Mawr, Pell Wheeler supported her students and colleagues by creating a welcoming and inspiring atmosphere within the school's mathematics department. Her students could not have had a better leader. Annita Tuller Levine recalled of her professor, "[M]ost of all I remember my father's words after he met you on Commencement Day in 1930. The thought of his daughter aspiring to be a female mathematician was a bit horrifying to him. However, after he met you, he said, 'Such a woman I would like you to be.'" Perhaps no greater compliment could be given to this beloved mathematics professor. The tributes of her former students highlight her influential role in shaping a generation of Bryn Mawr mathematics students with encouragement and enthusiasm.

The dedicated leadership of Charlotte Scott and Anna Pell Wheeler serves as a poignant reminder of the vital nature of building communities where members have role models who lead the way forward, teachers who inspire passion for the community's work, and mentors who provide unending support. This type of committed leadership promotes the growth of the community.

A century-old template for success

By 1940, fifty-five years after M. Carey Thomas and Charlotte Angas Scott began their careers at Bryn Mawr and about two decades after Marion Edwards Park and Anna Pell Wheeler assumed similar positions, the college had demonstrated significant mathematical productivity. Taken together, the contributions of these women not only offer inspiration but also a template for success as today's mathematical community aims to champion the cause of women—and that of other underrepresented groups—in mathematics. In particular, Bryn Mawr's successes might inspire us to enhance the functionality of our workspaces, create vibrant and rewarding mathematical connections, and offer strong role models and mentors for those around us. Following these examples will help us strive for the elusive ideals of excellence and equity in creating flourishing mathematical communities since, as we know, this work is far from over.

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9

The Smith College Center for Women in Mathematics

Patricia Cahn and Stefanie Wang

More than a decade ago, a growing number of women with non-traditional backgrounds in mathematics interested in pursuing graduate work in the discipline came to the attention of Smith College faculty Ruth Haas and Jim Henle. With support from NSF, Haas and Henle transformed this need into the creation of the Center for Women in Mathematics Postbaccalaureate Program. This one-year certificate program is designed to increase the number of women earning advanced degrees in the mathematical sciences. Community plays a prominent role in the Center in two ways: first, current and former students in the program form a mathematical community; second, the Center broadens the larger mathematical community.

The postbacc program serves students who want to pursue an advanced degree in mathematics, often a PhD, but who need additional coursework, research experience, or other support before applying to graduate school. Students in the program have a variety of undergraduate backgrounds: math majors who need additional courses for graduate study; STEM majors who want to study their area of interest via an advanced degree in applied math; majors in a subject far from math who discovered an interest in mathematics late in college, or after; and students who completed full math majors elsewhere but could benefit from the confidence provided by spending a year doing mathematics in a supportive environment. Students in the program are diverse in terms of race, ethnicity, gender identity, socioeconomic status, mathematical background, and type of undergraduate institution. Some come to the program right after college. Others work full time for many years before coming to the program. Some are single mothers. Many are students who, without an on-ramp like the postbacc program, would not have a means of entering the mathematical pipeline. The program welcomes applications from women and students with gender identities traditionally underrepresented in mathematics.

Smith College is a women's college, and forty percent of Smith students major in STEM, at least twice the national average for women. Students in the postbacc program take classes and work on research projects together with Smith undergraduates, many of whom are also preparing for graduate school. The postbacc students also act as mentors

and role models for our undergraduates, and our undergraduates enthusiastically comment on the diverse and valuable perspectives they bring to the classroom. Current and former Smith College math majors and postbaccs together form a robust network, which we refer to as the Smath community. Alums advise current students on their path through graduate school and possible career options afterwards, including government, academia, and industry. In one recent year, Smath graduates made up six percent of US women earning PhDs in mathematics. The program was recognized as one of the American Mathematical Society's Mathematics Programs that Make a Difference in 2011.

The postbacc program is designed to imitate key components of a graduate program, with additional built-in mentoring and an emphasis on peer collaboration. Students in the program take two or three math classes each semester; conduct research with faculty in small groups and present their work both to each other informally and at conferences; and participate in a seminar, Dialogues in Mathematics. The Dialogues seminar provides structured mentorship for the students: topics include both practical information for applying to and selecting graduate programs, as well as diversity and inclusion, work-life balance, reading, writing, and teaching mathematics. Students in the seminar also attend a weekly undergraduate-level math colloquium and interview the speaker, often a current or recent graduate student working in the region. Students can enter the program for one year starting either in the fall or spring, though most enter in the fall; this means most students in the program apply for graduate programs their first semester at Smith. They work on their applications together and support each other through the process of taking the GRE, forming a list of schools to apply to, and, eventually, choosing a program.

A pipeline into math

The idea for the program came about in two ways. First, there was a pattern among math majors at Smith: a student develops a serious interest in mathematics towards the end of her junior year, and wants to continue to study it in graduate school. But maybe the student took one semester of algebra, and no analysis yet, or vice-versa; this is a perfectly normal pace for a student who begins her college math major with Calculus I or Calculus II. On the other hand, most graduate programs require two semesters each of analysis and algebra, among other advanced courses. In many selective graduate programs, incoming students have already completed graduate coursework. Completing that coursework by the end of one's senior year of college requires careful planning and is out of reach for many students, particularly those who develop interests in mathematics later than their peers, or who do not have a head start in high school.

Second, the founders saw a need for a way into mathematics for students whose mathematical paths were atypical. One particular case was Susan D'Agostino, who majored in Anthropology at Bard College and later received a Master's of Arts in Teaching (MAT) from Smith and a PhD in mathematics at Dartmouth. Susan always enjoyed math, but after failing one test in high school calculus, she decided not to study math in college. As an undergraduate at Bard, she majored in Anthropology. After graduation, she worked for Bard's admissions office, where she interviewed prospective students. She noticed many of these students had an experience in math similar to hers, and she began to question why one setback caused her to stop studying a subject she liked so much. She set a goal of earning a PhD in mathematics and subsequently enrolled in math classes at Bard while

Postbaccs, math majors, and faculty in Spring 2018.

working full-time, starting with precalculus and calculus. She pursued one math class per semester while working over four years but knew that to achieve this goal she would need to devote even more time to completing prerequisites for graduate school; it was increasingly difficult to balance her advanced coursework with her job, which also involved quite a bit of travel. She looked for programs that would allow her to take undergraduate courses. The postbacc program at Smith did not exist yet, but Smith did have an MAT program which would allow her to take several math classes. Those classes, together with the ones she pursued at Bard, would give her the equivalent of an undergraduate math major. After six years of working full-time after college, she was admitted to the MAT program with a full scholarship, and applied to PhD programs her first semester at Smith. She completed her PhD at Dartmouth College in 2003. Today, she is a mathematician who writes math-themed articles for publications such as *Scientific American*; in the acknowledgments of her first book, appropriately titled *How to Free Your Inner Mathematician*, published by Oxford University Press, she thanks Smith College and several Smith mathematics faculty, including Jim Henle, Ruth Haas, Christophe Golé, and Patricia Sipe, for helping to free her inner mathematician.

The program directors received two five-year NSF grants to support the Center for Women in Mathematics, and the postbacc program in particular, starting in 2007 and 2012. The grants paid for postbacc student tuition and living stipends, as well as travel for invited speakers. The second of the two grants also provided funding for an undergraduate conference, Women in Mathematics in New England (WIMIN), which has become an important mechanism for the Center to bring together the local mathematics community outside of Smith. While these grants have now concluded, the program has become a vital part of the mathematics community at Smith, and continues to run with support from the college and individual faculty research grants.

Being a part of the postbacc program at Smith was a transformative educational experience for me. It showed me what it is like to be part of a supportive, diverse and inclusive mathematical community. It fostered a sense of belonging that sustained me when I doubted myself and my abilities in graduate school. I could go back and read the supportive letter another postbacc had written to me upon completion of the program, and remind myself of what I had to contribute to the mathematical community. The knowledge that I was part of the postbacc and Smath community gave me the strength to persist during challenging times.

—Rebecca Terry, PhD, University of Utah; now a Visiting Assistant Professor at St. Lawrence University

Forming a community of postbaccs starts with the admissions process. We look for students who can contribute to and benefit from a supportive community. A few of our students are starting a math major almost from scratch; most are filling in a few gaps; others could likely enroll in a PhD program already but have a compelling reason to spend a year in our program first. Recent students include: an art major who began auditing mathematics courses, including graduate-level courses, after college; a student from a large research-oriented university who majored in mathematics, entered the tech industry, and wanted to return to mathematics after a few years away; several students who studied mathematics in the context of a Great Books program but were missing the standard courses in algebra and analysis needed for graduate study; a chemistry and mathematics double major looking to combine her interests and enter programs in applied mathematics; and a single mother who put herself through school at a small college and needed additional resources and mentoring before applying to graduate programs.

We also look for applicants who can contribute to and benefit from the community-building and co-curricular components of the program: students with tutoring experience who can serve as TAs, students who work particularly well in groups, and students who have navigated atypical paths on their way to mathematics.

Coursework and research experience

Being part of the Smith postbacc program was the first time that I ever found a community in math. Being around a group of supportive people who valued collaboration and were upfront about when they were struggling made me enjoy doing math so much more than I ever had before. At my undergraduate institution, collaboration was (implicitly) looked down upon, and most people did math by themselves. Arriving at Smith and actually being encouraged to work with other people helped me realize how much more effectively I learn when surrounded by like-minded peers. Instead of seeing my desire to work with other people as a weakness (i.e., not being smart enough to figure out problems on my own), I came to see my ability to collaborate and learn socially as a strength (one that I continue to utilize). The Smith program made me far more confident in my mathematical abilities and resilient in the face of adversity, and I have had to call upon this confidence many times in graduate school!

—Sarah Brauner, PhD Student, University of Minnesota

The postbacc program is designed to replicate responsibilities of a beginning graduate

student, with additional built-in mentorship and an emphasis on collaboration. Students in the program choose courses with the help of an academic advisor, often one of the program directors. Students take at least two math courses each semester, in addition to a research course and the Dialogues in Mathematics seminar, for which they also receive course credit. The courses can be undergraduate courses at Smith, or courses at any of the other campuses in the Five-College Consortium (Amherst College, Hampshire College, Mount Holyoke College, and the University of Massachusetts). Smith faculty also offer independent study courses on topics not regularly offered in the curriculum, such as algebraic topology, representation theory, or Galois Theory. Occasionally one or two postbaccs are ready to take a graduate version of algebra or analysis at the University of Massachusetts, in which case we encourage these students to pair up with Smith undergraduates to take the courses together and form a study group.

Smith's undergraduate math culture is supportive and collaborative, and for many postbaccs, doing math in this environment is crucial for their success later. Smith's analysis course is a key example. Taught in an inquiry-based format, all work students complete aside from the two take-home exams is done in small groups. Students ask each other questions about their proofs and examples during in-class presentations, and edit and comment on each other's drafts on the course website. Students embrace this challenging course as an opportunity to struggle together productively and learn from each other's mistakes without judgement.

> *The largest impact that the postbacc program had on my experience in grad school was teaching me the benefit of community-based studying. In particular, my experience in topology at Smith, where we formed a study group, determined different ways to approach a problem (and our questions about each of those approaches), and sent a "sacrificial lamb" to ask the professor for direction based on our work proved to be an excellent method for graduate school. It taught me to be more prepared by listening to other approaches and answer the basic questions before trying to understand the nuances of the precise answer.*
>
> —Megan Sawyer, PhD, North Carolina State University; now Associate Professor at Southern New Hampshire University

Another key component of the program is that all students are required to conduct research with a faculty member in small groups. Of course, one major goal of this part of the program is to help students understand what it means to do research in mathematics. But it also provides an opportunity for students to practice taking mathematical risks in a low-stakes environment. All students are required to present their work to the department at the end of the semester, as well as at undergraduate conferences, such as Smith's own WIMIN conference, the Joint Mathematics Meetings, and the Hudson River Undergraduate Mathematics Conference. Students practice their public speaking skills, as well as their ability to answer audience questions.

Faculty members propose research projects at our first weekly colloquium of the semester, and the postbacc students, as well as interested undergraduates, rank their preferred projects. Some students work on different projects each semester and use the opportunity to figure out their mathematical interests; others continue with the same project for a full year and sometimes end up publishing a paper with their group.

Photo Credit: Caira Anderson.

Dialogues in Mathematics, Spring 2019.

> *The professors at Smith, and in particular the women professors, are strong role models. They dedicate their time and energy to be wonderful mentors and build such a strong, lasting community. Furthermore, their enthusiasm about their research is contagious and has heavily influenced my own mathematical interests. I continue to look up to them today and know that I could reach out to them at any time.*
>
> —Nicki Magill, PhD Student, Cornell University

In formal settings in the math building or in informal settings such as a gathering at a postbacc's house, postbaccs have the chance to talk to each other about research in a casual setting. It can be intimidating for graduate students (and even faculty!) to have informal math conversations at conferences or department teas, but this is how mathematicians exchange ideas and start collaborations.

The focus shifts away from "I want to do math but haven't followed a traditional trajectory" to "I tried this approach in research and it didn't work, but here is what I learned." Failure is a normal part of research, as one can take many wrong turns before finally stumbling across the right viewpoint and right computation to nail down a result. The environment at Smith and in the postbacc program creates a space where students can talk about their dead-ends as a way to move past failure and reassess their work so that they can be successful. It is far better for a person to experience failure and move on in a healthy way in a supportive environment than to hit those roadblocks in a graduate program that may be less supportive.

Advising and mentoring

> *The Smith postbacc program was instrumental in helping me make a well-informed decision about where to apply for graduate school, in particular with regards to finding*

programs with a strong community of graduate students. Without the advice from Smith professors, I would have had no idea about how cultures differ between graduate schools. I am sure that choosing a graduate school where community is strongly valued has been integral to my success thus far.

—Sarah Brauner, PhD Student, University of Minnesota

Student-faculty mentoring and advising relationships, both formal and informal, play an important role in our community. Formal mentoring takes place primarily through the weekly Dialogues in Mathematics seminar. Dialogues is a required course for all postbaccs, and provides structured time for postbaccs to gather and connect with each other and with faculty mentors. Graduates of the program have commented on the importance of coming together as a community on a regular basis.

The class runs once a week for two hours after the department's weekly undergraduate math colloquium, and is broken into two one-hour parts. During the first hour, students interview the speaker. The speakers are often graduate students or early-career faculty in mathematics. Occasionally, the speakers are former postbaccs. Topics discussed range from the application process (e.g. choosing graduate programs to apply to, managing the financial logistics of applying to graduate programs, visiting programs once admitted, and selecting a program to attend) to personal details (e.g. overcoming personal or professional hardships, returning to math after time away, or navigating impostor syndrome).

Speakers often invite students to email them with follow-up questions. As the speakers are not all affiliated with Smith or the postbacc program, the seminar offers opportunities for postbaccs to form mentoring relationships and friendships with members of the wider mathematical community. These conversations play an important role in helping students through the graduate school admissions process, giving students a concrete picture of what they can expect once they begin graduate school, and understanding how department and graduate student culture varies between institutions. The speakers serve as role models for the students. Graduate student speakers, in particular, have a special impact on postbaccs. Information on creating collaborative study groups, training for teaching positions, or preparing for qualifying exams is not shared from hazy recollections. These are the mathematicians still in the trenches of graduate school and who can give an accurate picture of what daily life looks like as a graduate student.

In the fall semester, the second hour of Dialogues focuses on preparing applications: studying for the subject GRE, identifying and obtaining recommendation letter writers, writing personal statements, and selecting programs to apply to. In the spring, the second hour of Dialogues helps students develop tools they will need to be successful graduate students, as well as a glimpse into life after graduate school: time management, reading and writing mathematics, implicit bias and stereotype threat, work-life balance, and career paths in both academia and industry.

Another important function of Dialogues is that it is a place for students to articulate, share, and navigate concerns that may seem unique to their own experience, but are in fact quite common. As students begin to curate their list of prospective graduate programs in the fall, the number of existential crises and crises of faith may approach a local maximum. Concerns arise along these lines. *How does one choose graduate programs as a non-traditional graduate school applicant? Is the journey worth it? Is graduate school the*

right choice? What if I am not good enough? What does "good enough" even mean? Though each postbacc is motivated and capable of successfully completing a PhD program, they may still grapple with these difficult questions. During this process, peers and faculty provide guidance, a friendly ear, and a space for students to express and work through these concerns.

Beyond Smith

Of the 53 postbacc graduates from the May 2008–May 2013 cohorts who entered graduate programs (this includes both terminal master's and PhD programs), more than a third have completed PhDs so far. Others from these cohorts are still in PhD programs and are expected to finish soon, or entered PhD programs after completing master's programs or taking time off. Students who entered graduate programs after 2015 would not yet have completed a PhD at the time this article was written, since this typically takes at least five years. Many Smith math majors have received PhDs during this time as well. Indeed, the postbacc program enriches our department culture in ways that make graduate programs more accessible to our undergraduate majors: we have expanded our undergraduate course offerings, research opportunities, and co-curricular events. Together with postbaccs, Smith students make up an unusually-large percentage of US women receiving PhDs in mathematics.

Graduates of the program work in industry, government, and academia. They work as data scientists at Target, Etsy, and Netflix, and in government at the NSA and Department of Defense. They hold faculty positions at Eastern Connecticut State University, Southern New Hampshire University, the University of Connecticut, Brooklyn College, Providence College, Gallaudet University, and St. Mary's College of Maryland, among others.

The culture in the mathematical community is certainly improving, but graduate school can still be extremely isolating for women and members of underrepresented groups. Mentors and role models may also be in short supply. Establishing friendships and networks takes time. Through social media and email chains, postbaccs support one another even though they may not be in close geographical proximity.

> *I accidentally dialed a Smith postbacc close to midnight my time which would have been around 1:00 A.M. her time while we were both in grad school. A few years had passed since we had completed the postbacc program, and we really hadn't communicated much with each other since then. Not realizing I had dialed, all of a sudden I heard her voice asking me if everything was okay and if I needed anything. I was okay; just tired and confused as to how I had inadvertently phoned her. For me, this incident reflects the strength and power of the postbacc community. A postbacc will pick up the phone for you at 1:00 A.M. when you are both in grad school.*
>
> —Rebecca Terry, PhD, University of Utah; now a Visiting Assistant Professor at St. Lawrence University

Still, we've found that the most effective way for students to support each other after Smith is through in-person reunions. The Smath community gathers every year at the Joint Mathematics Meetings. Through these reunions, postbaccs from different years connect and offer advice about later stages of graduate school and early-career, such as

choosing an advisor and going on the job market in both industry and academia. Every fall, Smith hosts the WIMIN Conference, which gives students in the region an opportunity to present their research. Local postbacc graduates often attend, particularly within a year or two of starting their graduate programs, and reconnect with peers and faculty mentors. Smith has also hosted several reunion conferences for Smith mathematicians at the college; when the initial NSF grant was active, the program was able to fund travel for participants.

> *During my first year of graduate school, I lived with a fellow Smith postbacc who was entering the program at Minnesota concurrently. We initially got to know our cohort by hosting a potluck that featured a geometric puzzle—how to get our new couch through the front door! Later, not unlike my experience at Smith, we would spend hours with our peers at the blackboard in the student lounge, puzzling out problem sets. To maintain school-life balance, we developed a sort of unspoken rule to avoid math conversations at home unless it was an emergency (i.e., I'm incredibly stuck and the assignment's due tomorrow). Whether at school or at home, having another Smathie as a close support during this first year helped me acclimate to grad life.*
>
> —Kate Meyer, PhD, University of Minnesota; now Assistant Professor at Carleton College

By now, the program has established relationships with several universities, where many of our students have been successful. Our students have completed PhDs at Wesleyan (2), the University of Massachusetts, the University of Minnesota (5), North Carolina State University (4), Duke (Statistics), Florida State University, Cornell, Iowa State University (2), Harvard (Biostatistics), and the University of Utah. At North Carolina State and the University of Minnesota in particular, there are often several postbaccs in the program at any given time, and they are more easily able to recreate the support they found at Smith in their new environment. In particular, the program equips students with skills they need to thrive after they complete the postbacc program.

> *One of the most powerful parts of the postbacc community is its lasting impact outside of Smith. A group of postbaccs from my year and I are still in regular contact sharing our graduate school experiences. They regularly listen to my journey searching for an advisor, encourage me when I struggle on an exam, help me craft various emails, remind me that I can succeed as a mathematician, and are able to empathize on our shared experiences of being a woman in graduate school. Listening to their experiences reminds me that graduate school and doing mathematics is difficult for everyone in some way or another. Usually, it takes me some time when starting a new program to find people that are able to understand what I am going through who I am also comfortable sharing my struggles with, but the postbacc program allowed me to have such a great support system from day one of graduate school.*
>
> —Nicki Magill, PhD Student, Cornell University

We conclude with a few observations. When we think about what it takes to be successful in graduate school, we often think about preparation in terms of mathematical content. But graduates of the program rarely comment on course content when they think about how the program helped them succeed. Moreover, we've seen students from a wide variety

of mathematical backgrounds earn PhDs, including students who came to our program with little more than the official prerequisites of linear algebra and multivariable calculus. Yes, content is important, but adjusting the culture of a department can make that content accessible to a wider range of students by increasing their confidence and their ability to ask for help. Structured and unstructured mentorship are both essential. At Smith, structured mentorship includes research groups, required for all postbaccs and open to all interested undergraduates, as well as the weekly Dialogues seminar and colloquium. Unstructured mentorship includes encouraging students to go to office hours, or form study groups, and connecting students to alums with similar career goals.

The next steps for the program are to expand and strengthen the network of current and former postbaccs in order to connect postbaccs from different cohorts, career stages, and professions. Currently, postbaccs meet at the regional WIMIN conference, reunions at the JMM, as occasional guests at the Dialogues seminar, and through informal networks. We plan to regularize alum speakers at the Dialogues seminar, to construct something like virtual Dialogues seminars that can reach both current students and alums, and to build a more robust asynchronous outreach network to keep alums connected.

Another vital step is for the program to solidify longterm funding structures to ensure that students from diverse socioeconomic backgrounds, including students who are not US citizens/permanent residents, can continue to access our resources.

> *I have tried to pay forward the Smith postbacc experience in my various roles as a graduate student, instructor and mentor, and through different outreach activities. The support and inclusion that I experienced as a postbacc at Smith is something that I carried with me throughout my graduate career and have tried to establish in my classrooms as an instructor.*
>
> —Rebecca Terry, PhD, University of Utah; now a Visiting Assistant Professor, St. Lawrence University

The postbacc program's goal of changing mathematical culture to include collaborative earning and respect for both different perspectives and non-traditional mathematical paths is an important component of the goal of increasing diversity in the mathematical pipeline. Those who experience the Smith program go on to spread that culture wherever they go.

Acknowledgments

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Patricia Cahn is one of the current co-directors of the postbacc program at Smith College, together with Candice Price and Julianna Tymoczko. A graduate of Smith herself, she returned to Smith as Assistant Professor in 2016.

Stefanie Wang is Visiting Assistant Professor at Smith College and an alumna of the postbacc program. She earned her PhD from Iowa State in Spring 2017.

10

Math Alliance
Investing in Tomorrow Today

Alexander J. Barrios, Ranthony A. C. Edmonds, and Roberto Soto

Originally established in 2001 as a collaborative effort between three Iowa State Regents universities—the University of Iowa, Iowa State University, and the University of Northern Iowa—and several HBCUs (Historically Black Colleges and Universities), the Math Alliance aims to increase the number of individuals from underrepresented groups who earn PhDs in the mathematical sciences. The Math Alliance began by offering summer research experiences for undergraduates (REUs) and has now developed a network of mathematicians to mentor and nominate students to become Alliance Scholars and help them navigate the graduate admissions process. This network has since extended beyond the three Iowa State Regent universities to include Graduate Program Groups (GPGs) at the doctoral and master's levels across the country, each with the goal of creating departmental climates where underrepresented students can thrive while pursuing a degree in a mathematical science. Since 2005, over 100 Alliance predoctoral scholars have gone on to earn PhDs.

The Math Alliance has hosted an annual Field of Dreams Conference since 2007, which celebrates the work of underrepresented mathematicians and provides undergraduate Alliance Scholars with access to potential graduate programs and opportunities. The highlights of the conference include interactive panels, an REU fair, a graduate school fair, and a career fair. In recent years, the Math Alliance has also created regional alliances to further its goal of community building within the mathematical sciences. Recently, the Alliance has created the Facilitated Graduate Applications Process (F-GAP) program to assist senior- and master's-level students in the application process for graduate school. F-GAP participants are paired with a facilitator who provides feedback on application materials and potential GPGs that would make a good fit for them. There is a time set aside at each Field of Dreams conference for F-GAP mentors and mentees to talk in person. In 2019, the Alliance began a partnership with the Institute for Mathematics and its Application (IMA) for a summer workshop between F-GAP students and their mentors.

Tim McEldowney, Alvaro Cornejo, Tayler Fernandes Nuñez, Kendall Bowens, and Alex Barrios at the Field of Dreams Conference, 2019.

Since its implementation, eighty percent or more of F-GAP participants have gone on to graduate school each year.

This chapter offers reflections from each of the three authors about their experiences with the Math Alliance and how it has shaped their mathematical careers. This in turn has inspired us to transform the mathematical trajectories of our students. We hope these stories prove useful to other members of the mathematical community who champion the cause of underrepresented groups in mathematics and look to create thriving communities of their own. After reading our firsthand accounts, we encourage you to research more on the Alliance's fruitful process of welcoming more diverse scholars into the mathematical community and providing them with the ongoing support and role models needed to become professional mathematicians.

Alexander J. Barrios

In the summer of 2008, I participated in the Alliance's REU at the University of Iowa. At the time, I had just finished my freshman year at Miami Dade Community College and believed that calculus was the peak of mathematical knowledge. The REU exposed me to new branches of mathematics and offered me the opportunity to conduct research in differential geometry. It also provided me with my first research talk at a conference through the Iowa State Regents Schools Summer Symposium which was held at the conclusion of the REU.

A particularly important facet of the Alliance REU was its mentorship program which helped me feel a sense of belonging and community. In many ways, the mentorship program was an inflection point in my academic pursuits. Prior to attending the Alliance REU, I had little knowledge of what a PhD was or what the process was like. Through the mentorship program, I had the opportunity to have one-on-one conversations with mathematicians on what graduate school is like and the various job opportunities available to recipients of a PhD or master's degree in the mathematical sciences.

One moment that stands out from that summer is being in Phil Kutzko's office and listening to his life journey and how he came to earn a PhD in mathematics. He encouraged me to consider pursuing a PhD in mathematics and to transfer to an institution that offered a stronger math curriculum so that I could improve my chances of gaining admission into a doctoral program. This conversation galvanized me to pursue a PhD in mathematics. I transferred to Brown University the following year to earn my ScB in mathematics and continued on to receive my PhD from Purdue University.

Years later, I would attend the Field of Dreams conference as a graduate student. The conference is one of the few annual opportunities in mathematics tailored to underrepresented mathematicians, and I look forward to attending each year. I remain awed by the Math Alliance's continued devotion to implementing their mentorship program at a national level. Their success is evident at the Field of Dreams Conference. As a graduate student attending the conference, I received mentorship from faculty members who gave me invaluable advice about the job market as well as feedback on my application materials. I was also able to provide mentorship to undergraduates who were interested in pursuing a PhD in the mathematical sciences. In recent years, I have had the opportunity of attending as a faculty mentor, and this past year I was joined by some of my REU students who benefitted tremendously from the conference's graduate school fair and panel. But more importantly, they were happy to be a part of a supportive community that valued their growth as mathematicians.

Through the Field of Dreams Conference, I have been able to create a social network of supportive friends and mentors and it has been a pleasure to see the conference grow with each passing year. It is a truly inspiring conference that celebrates the work of underrepresented mathematicians. This, in turn, demonstrates to students in the audience that they too can pursue a PhD in the mathematical sciences.

Ranthony A. C. Edmonds

In a somewhat random leap of faith during my undergraduate studies, I switched my major from pre-med biology to mathematics, effectively starting from scratch by taking Calculus 1 the second semester of my junior year of college. One large disadvantage of beginning a math major so late is that I never became particularly immersed in the mathematical community at my undergraduate institution. I took the exact number of courses needed to graduate with the major, I never studied with others, never attended any math talks, was unaware of any enrichment opportunities, and received very little advice with regard to applying to graduate programs. In a touch of serendipity, a cold email to the math department at Eastern Kentucky University (EKU) inquiring about post-baccalaureate coursework led to a fully funded graduate assistantship for a Master's Degree in the Mathematical Sciences. It was during this program that I decided to pursue a PhD.

Attending graduate school at the University of Iowa, which subsequently led to my participation in the Math Alliance, has had a profound impact on my mathematical career. The graduate community at Iowa was collegial, collaborative, and diverse. I met with Professor Philip Kutzko once a week to help with my transition to the University of Iowa, and I learned about the Math Alliance. I attended my first Field of Dreams conference my second year of graduate school in 2014. It seemed surreal to be surrounded by so many

Photo Credit: JKE Photography. www.jkephoto.com

Douglas Mupasiri and Ranthony A. C. Edmonds speak on the How Do You Know When You Know Math? Panel at the 2019 Field of Dreams Conference.

individuals invested in my success, and to have a space to talk openly about the intersections of being a black female mathematician. Here was everything I had been missing as an undergraduate student! I distinctively remember the Doctoral Experiences panel, where only students were allowed in the room and people were open and honest about their experiences as graduate students.

I attended the conference two more times as a graduate student. I received meaningful tips about completing my dissertation and I moderated the Doctoral Experiences panel. I also received advice about the job market. In fact, I talked about postdoctoral opportunities at The Ohio State University during the graduate school fair at the Field of Dreams Conference in 2017. The first year of my postdoc at The Ohio State University I came back to Field of Dreams and talked on the Fields of Success panel. I not only talked to graduate students about my experiences, but I also talked to faculty members about developing a research program. I had frank conversations with faculty about the types of things I should do during my postdoc to position myself for the type of mathematical career I want.

From a new graduate student to a postdoctoral fellow, the Alliance has helped me navigate my mathematical career. In particular, each time I attended the Field of Dreams Conference, I left with new connections—new mentors outside of the University of Iowa and new friends. I am now an Alliance faculty mentor and in 2018 I brought a student with me to the Field of Dreams Conference who had also been navigating his mathematical journey alone, just like I had been many years ago. I will continue to help the Math Alliance grow and adapt to the new challenges that underrepresented students face in gaining access to and matriculating through doctoral programs in the mathematical sciences. I always look forward to opportunities to introduce new people to this dynamic community of mentoring excellence.

Roberto Soto

I learned about the Math Alliance in quite a unique way and much later than most people that attend the Field of Dreams Conference. In the fall of 2009, I was thinking of transi-

tioning from a quasi-administrative position in a school district to earning a PhD in Math. I was looking for a PhD program that believed in providing a supportive community to its students and the University of Iowa was the first school that my mentor mentioned. So my wife and I decided to visit Iowa and were fortunate enough to meet Phil Kutzko, who immediately invited us to the Alliance-sponsored Field of Dreams Conference the next week in Iowa City.

As I attended the conference, I was astounded by the number of Latinx, African American, and Native American students at a math conference. I had never experienced this before. It was inspiring and I definitely felt that there was a place for me in the mathematical community. I was also able to meet many students from the University of Iowa who confirmed what my mentor had mentioned. Thus, the Alliance helped me feel at home in this community of mathematicians, although at this point I was not sure if I had anything else to be gained from the Alliance.

As a student at Iowa I was so focused on graduating that I rarely had time to participate in Alliance events, but right before I graduated, I had the opportunity to attend one more Field of Dreams Conference in Arizona. The Alliance and the faculty that attended the conference welcomed me with open arms again—as if I had never left. It is through the Alliance that I have met most of my mentors who have helped me navigate my career. The Alliance didn't just make me feel welcome once and inspire me to pursue a PhD, it has continued to provide me a space to collaborate with many mathematicians that share my goals. I have learned so much by being part of this community, and I have found many support networks because of it. I have participated in Project NExT, am a member of

Photo Credit: Roberto Soto.

Roberto (center back) with his students at a Field of Dreams conference.

MESCal (Mathematics Equity in Southern California), and am a member of the Pacific Math Alliance because of my association with the Math Alliance. Even the opportunity to be on the faculty at California State University, Fullerton came about because of my association with the Math Alliance. Each of these communities has supported me through many milestones of my career. Moreover, my involvement with the Alliance now allows me to pay it forward to students who attend the Field of Dreams Conference. Many times I wish that the Alliance had existed when I was an undergraduate in the 1990s so I would have chosen this career at an earlier stage. Moreover, it would have been great to have met role models like Bill Vélez, Rodrigo Bañuelos, Minerva Cordero, and James A. Mendoza Alvarez. But now I have, and my students benefit from this knowledge.

Today for tomorrow

Our reflections reveal keys to the success of Math Alliance: building a community where students feel like they belong helps strengthen their resolve to continue on in mathematics. We hope these testimonials might inspire other mathematical communities to support mathematical excellence for all. The Math Alliance allowed us to see ourselves as mathematicians and showed us that there is long-term value from communities that invest in strategies to guide, prepare, and inspire developing scholars—especially those who might otherwise navigate their careers alone. Mentors who model possibilities and encourage students to see their own potential to succeed in mathematics are an important part of the Alliance's success. Finally, the Math Alliance's cycle of mentorship promotes beautiful possibilities for exponential growth when one group finds empowerment and can in turn help advance the next generation.

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Youngstown State AWM
Mentorship and Fellowship

Monica Busser, Alanis Chew,
Jacquelyn Ehko, and Ashley Orr

Introduction: big-picture structure

The Youngstown State University (YSU) chapter of the Association for Women in Mathematics (AWM) had its most recent revival in 2013, when the then-Chair of the Department of Mathematics and Statistics, Dr. Angela Spalsbury, saw a need to attract more female students and help the current students feel a sense of community. The main goals of AWM are to mentor and encourage women and girls as they prepare for careers in the mathematical sciences, to provide them with a greater understanding of the contributions of women in the mathematical sciences, and to increase knowledge of, and greater interest in, the mathematical sciences, including pure and applied mathematics, statistics, and their applications. Since its inception, the Association has created multiple programs to address these objectives, including outreach to K–12 students, a Women's History Month Colloquium, network opportunities with professional female mathematicians, and professional development and technology workshops. The group also hosts events to inform the YSU community on the struggles that women and minorities face and, more importantly, on ways allies can mitigate these struggles.

AWM is open to all college students, regardless of major and gender, as long as participants support our goals and love math. In this chapter, we highlight some of the programs, events, and struggles that the YSU chapter of AWM has experienced since its rejuvenation in 2013.

Early challenges

Building momentum When our chapter revived in 2013, there were 26 mathematics faculty members at YSU including only four women tenure-track professors. Although we had some female students, few were active in the department. AWM was revived, in part, to address this lack of visibility. Like many student organizations, it took time for the YSU

AWM to build momentum and establish ongoing events and activities. For the first two years, for example, we hosted a Sonia Kovalevsky Day, but ran out of funding and human power to continue. We also ran a mathematical scavenger hunt for our students for two to three days, but this, too, lost momentum. However, in recent years, students have been more active in the organization and more vocal about their interests and needs, starting programs that are more likely to endure over time (such as the Bigs and Littles (described below), the Pancake and Movie Night, and the Overleaf and Beamer workshops, etc.). We promote AWM by emphasizing our love for mathematics and equality. Our organization currently has 49 members, including eight men, with about ten to fifteen core members who are instrumental in shaping the future of the group. We partner with the YSU Department of Mathematics and the YSU Chapter of Pi Mu Epsilon to host events and attract members. We have found that having a plan of activities for the semester and proper training for new officers form vital components of the success of our organization.

Funding Our AWM chapter has been lucky to have had generous support from the Department of Mathematics and Statistics, as well as from the college and the university in general. One of our members, in her role as President of the YSU Student Government Association, secured funds to help finance different events for all student organizations around YSU. However, given the availability of these funds, our chapter does not have a strong culture of fundraising and sometimes struggles to find specific funds to host certain events.

Bigs and Littles: sense of community

Our chapter started a mentoring program called "Bigs and Littles" in Spring of 2017. Through this program, any interested first- or second-year female math major is assigned to a third- or fourth-year female math major who has exhibited excellence in her early mathematical career. In this program, Bigs and Littles are assigned to one another based on career plans, interests, and any preferences the Little specified. Designed to correct the "leaky pipeline" effect, the program offers students a sense of belonging in the department and provides them with someone to give them advice and support. We begin the academic year with a fun event to introduce any Bigs and Littles who do not already know each other. After this, most Bigs and Littles decide to meet informally. Bigs have proven to be a great resource for information on opportunities like research, conferences, REUs, and graduate school. This program has also increased participation of younger students in our other professional development programs detailed below.

Since beginning "Bigs and Littles," there has been a spike in first-year math majors wanting to pursue research. In the first year of the program, many Littles expressed interest in research and their Bigs were able to refer them to Dr. Prieto Langarica, who often advises undergraduate research. When these seven first-year AWM members approached Dr. Prieto Langarica, she formed two groups that were advised in part by one of our Bigs, a senior with ample mathematical biology research experience. This research resulted in these seven students attending the 2017 MAA MathFest as rising sophomores. The first group researched bone metabolism and bone reconstruction and the second researched muscle fiber formation processes during fetal development. From this experience, the stu-

Youngstown State AWM members receiving the AWM Student Chapter Award for Professional Development at the 2017 MAA MathFest.

dents learned how to use MATLAB, prepare a math talk, use LaTeX, and conduct research in mathematics.

In 2017, the YSU chapter of AWM was awarded the AWM Student Chapter Award for Professional Development for the Bigs and Littles mentoring program by the national Association for Women in Mathematics.

Other chapter events

Throughout the academic year, we host both fun and educational events. Our events include:

AWM Pancake/Waffle Night We begin the semester with an informal meeting, explaining what we do and introducing our members while enjoying pancakes and waffles with different types of toppings.

Overleaf/LaTeX and Beamer Workshop We started hosting LaTeX workshops every semester, partnering with Overleaf as our official LaTeX platform, since a few of our professors actually require students to submit their assignments in LaTeX. Students may find this requirement challenging if they have never heard of LaTeX. As future mathematicians, we believe our members should be equipped with the proper tools and experiences to write in a mathematical environment. We also introduce the basics of creating a Beamer presentation, as many members present at national conferences.

REU Workshop Typically, a few of our members participate in REUs over the summer. We ask them to give a short presentation explaining what an REU is, what the application process was like, their experiences at their REUs, and any advice for students interested in applying to an REU in the future.

Photo Credit: Emilee Smrek—Youngstown State University Chapter Officer of AWM.

Youngstown State AWM officers preparing for Pancake Night.

Movie Night As most college students are loaded with stress and homework, we understand the importance of socializing. About every other month, we watch a math-related movie and work on homework together. This provides a comfortable environment for our members to relieve some stress and commiserate with each other. Occasionally, we volunteer with Mats for Mahoning while we watch our movie. Mats for Mahoning is a volunteer project where we crochet mats out of plastic bags for the homeless around the Mahoning Valley in Youngstown.

Game Night Towards the end of the semester, we have a night with math-related games for our members to play. We believe that sometimes we need to take a break from all the homework and have fun with friends.

Dodecahedron Night with Tea and Hot Chocolate Origami has been a hit with our members, so much so that we have incorporated a night where we make dodecahedra out of square memo pads. This workshop utilizes some graph theory and AWM members also lead this workshop at YSU MathFest, a day of math for high school students.

Snacks at the MAC During the week before Finals, AWM sponsors snacks (cookies, fruits, and vegetables) for students who come to the Mathematics Assistance Center (MAC). While promoting this event, we hope to encourage students to come to the MAC for help with their math classes and for info on our organization.

Our vision of the future

As with many other young organizations, we are filled with hopes and plans for what is to come. Here are some ideas we are currently working on for the future.

Partnerships with Other Chapters There are several colleges and universities with AWM chapters within a one hour drive from YSU. We have been in touch with some of

them, like the University of Akron chapter, and we would love to start planning different events together, such as speakers, gatherings, and fundraising events. These partnerships will allow us to expand on our community, exchange ideas, and improve the overall lives of female students in mathematics around our area.

Pure Math Workshop Since we have members who are not math majors and math majors who have not taken pure math classes, we want to expose them to what pure math is all about. We plan to have professors or upperclass undergraduates talk about Abstract Algebra, Graph Theory, Combinatorics, Analysis, and Topology.

Research Workshop One of our main goals is to promote undergraduate research in mathematics. We believe that, regardless of their major, every student should get involved in mathematical research as early as possible in their undergraduate career. To facilitate this goal, our chapter plans to host a series of panels/workshops where current students involved with research and faculty talk about their experiences and give advice to incoming research students.

Bringing Back Outreach For a couple of years after the chapter's revival, AWM hosted a Sonia Kovalevsky Day for middle school girls. This was a wonderful outreach program which also served as a recruiting tool to attract women to the mathematical sciences. With the help of the chapter advisors, we would like to seek funding to bring back this event.

From our members

Alanis Chew

I had never actually considered pursuing mathematics until I took Calculus 2. I was a business major who had already met all the math requirements, but remembered how much I enjoyed Calculus 1 in high school, so I enrolled in Calculus 2 the summer semester before I started college in the fall. I had such a great experience, I knew I wanted to take more math classes and possibly pursue a minor in math. As a first-year student, I had no idea of what I could do with math. Wanting to be more involved, I came across AWM on the list of student organizations. I reached out to Monica Busser, who was the President of the YSU Chapter of AWM at that time. She responded with such excitement and happiness, sharing what it meant to be in AWM and what fun events they had in store; I could feel her passion for AWM radiating from that email. She mentioned the YSU MathFest, an event for high school students to participate in workshops led by math professors and students. As a senior in high school, I participated in the YSU MathFest, and I wanted to pay it forward by volunteering for the event as a college student now.

When I met Monica for the first time, during our lunch break at the YSU MathFest, she was a ray of sunshine. We got to know each other, and I started attending meetings. There, I met my best friend, Julie, who is a mathematics and environmental science double major. Monica had started the Bigs and Littles Mentoring Program and I was lucky enough to be paired with Monica as my Big and Julie as my "sister." I cannot begin to express how much Monica has changed my life. As my Big, she would invite us over to her apartment for sleepovers, where we would talk about math, music, and life while making sushi. We

would talk about our struggles and comfort each other. She had so many experiences and so much advice to share with us. She exposed us to research, REUs, conferences, and many other things. She loved algebra and only praised our math department.

Not long after I met Monica, I scheduled a meeting with the then math department chair, Dr. Angela Spalsbury. She made such a good impression on me, I decided to add math as my second major. Just from meeting Dr. Spalsbury once, I knew she was incredible. Soon after, AWM planned an alumnae and current members get-together. There, I was introduced by my Big to Youngstown alumna Ashley Orr and to my future mentor and research advisor, Dr. Alicia Prieto Langarica. Ashley also studied economics and mathematics. Having the opportunity to pick her brain about her experiences was inspiring; she studied abroad at the London School of Economics, interned at the Federal Reserve Bank of Cleveland, and did interesting mathematics and economics research. Despite accomplishing so much, Ashley was incredibly humble and down-to-earth. She wanted to know about me and was willing to help in any way possible.

Dr. Prieto Langarica is one of AWM's faculty advisors and one of the most amazing human beings I have ever met. When I first met her, she was talking about all the interesting research she was doing with her students and I asked if I was able to get involved. She said yes and the next thing I knew, I was doing research, learning how to code, and presenting at a national conference as a freshman in college. It was magical. I could not have done all that without AWM and its continuous support. Now, as I complete my third year of college, I can proudly say that I have been involved with three research projects, presented at four national conferences all over the country, participated in national and international math competitions, and met incredible mathematicians. In a field highly dominated by male mathematicians, I have never once felt inadequate because of the support and role models I have had. Monica, Dr. Spalsbury, Dr. Prieto Langarica, Ashley, and all the other wonderful members of AWM have always made me feel strong and capable of great

Sarah Elizabeth Odidika, Julie Phillis, Gabbie Van Scoy, Alanis Chew, and Mirella Boulus after Gabbie's Regional PME conference presentation.

things. Even during challenging and frustrating times, we constantly remind each other of how amazing we are and how we are each other's inspiration. I tell them all the time how much I love and appreciate them. At the end of the day, that is what AWM is, a family-like community whose members love and support each other.

Jacquelyn Ehko

From the time I was a young, I knew that math was going to be a special part of my life. It would (and still does) bring me immense joy to solve problems and learn new things. I have always spent so much time doing math and especially enjoyed tutoring my classmates whenever they were having trouble. As a result of this love for mathematics and my strong desire to help others, I knew that mathematics education was the field I would pursue a degree in during college.

I started at Youngstown State University in the Fall of 2016 and was hesitant to take on too many commitments at first. I had been heavily involved in high school, and I wanted a break in college to focus on my school work. That break did not last long. Beginning the spring of my freshman year, I joined several organizations and began doing research with the Department of Mathematics and Statistics. This is arguably one of the most meaningful decisions I have ever made. I started out doing bone cell research and math modeling with a small group of young women and Dr. Prieto Langarica as our advisor. Since then, we have presented our work at both the MAA MathFest in Chicago and the Nebraska Conference for Undergraduate Women in Mathematics in Lincoln. Both of those opportunities gave me an unparalleled experience with math professionals. Next, I began doing research on Sentiment Analysis with a different group of talented individuals which I presented the next year at MAA MathFest in Cincinnati.

After our chapter of AWM at Youngstown State won an award at the MAA MathFest in Chicago, I was very curious about the organization and I wanted to get involved right away. My research partner, Julie, welcomed me to the AWM. The Association for Women in Mathematics has meant so much to me because of our tight-knit community of women. I have really enjoyed getting to know our members better, and they have become a big part of my life. Without our chapter's co-advisor Dr. Prieto Langarica's belief in me and drive to push me forward, I do not know where I would be today. The AWM and the support I have received from our members and advisors contributed to my success in college. I am beyond thankful for the friends and family that I have found in AWM, and I would never want to trade this experience.

From our alumnae

Monica Ellen Busser

As a freshman mathematics education major, my ability to succeed in mathematics had been questioned by a few others, but never by myself. Linear Algebra, however, challenged my confidence. Suddenly I felt as if I was not capable of pursuing the field that I loved. Thankfully, while I didn't believe in myself, my classmate, Crystal Mackey, did. Crystal was a year older than me and had I not met her, I doubt I would have been able to even complete the math classes necessary for a BS in mathematics education. Crystal provided

unwavering support and assured me that I was not the only one who felt unsure about myself as a student of mathematics. She also helped me realize that having this view of myself did not make it true.

With this new confidence, I put all my efforts into my math classes the next semester, and when they went well, I decided to change my major to pure mathematics. When Crystal heard this, she strongly encouraged me to apply for REUs. I was certain that I was unqualified, but Crystal didn't take no for an answer. To humor her, I applied to a couple. To my surprise, but not to Crystal's, I was accepted to and participated in an REU that summer and the summer after.

In my senior year, I realized the extent of my good luck that came from meeting Crystal. It is completely conceivable that Crystal could have taken another Linear Algebra class. Had this happened, she would have been just another person I saw in the hall of the math building, too afraid to talk to for fear of them discovering that I wasn't as smart or as accomplished as I should have been.

It was important to me that future generations of Youngstown State female math majors weren't reliant on luck for finding the perfect mentor. Thus, in my senior year, I worked with Emily Hoopes, Gabbie Van Scoy, and Dr. Prieto Langarica to establish a mentoring program for all freshmen and sophomore female math majors. The richest, warmest memories I have from Youngstown State University are the times I spent with my mentees, both as a friend, and as a counselor. All of the expertise on applying to REUs, writing a curriculum vitae, preparing for a research presentation, writing a grant for travel funds for a conference, etc., was passed from Crystal to me, and then from me to my Littles.

My final event with the Youngstown State Mathematics department was MAA MathFest in Chicago, three days before I moved to graduate school. At this event, I was able to witness the presentations of the first generation of YSU Association for Women in Math Littles. Were I to prove the Riemann Hypothesis, watching these students present their research would still be the proudest moment of my young career.

Ashley Elizabeth Orr

I was raised by two strong-willed women, my Grandma and my Mother. In grade school, I quickly fell in love with mathematics, and at home I was met with encouragement. Gram gave me old ledger paper from her work to play chief financial officer, and in the checkout lane when we were at any store, we would compete to see who could add up the bill the fastest. Mom would listen to me recount all the things I had learned in math class. When I declared I wanted to be a mathematician during my college search, they both radiated pride.

I share this because this was my prior experience with math. Fast forward a few years, I remember feeling anxiety by being the only one, or one of a few, women in my math courses; feeling anxious when I heard stories of the difficulties women in the field face; feeling conflicted for being celebrated for my success in this male-dominated field; and worrying that my gender was preemptive of my work.

This is why the Youngstown State University Chapter of the Association of Women in Mathematics and the community of women students and faculty in YSU's mathematics department were so critical to my well-being, to my success, and to my personal and pro-

fessional mission in life and work. This community helped me work through these qualms and change the frame for how I understood my success in mathematics. This community helped me realize I was successful **because of being a woman not in spite of it**.

There are so many examples I could share of this community in action, but for the sake of brevity, I will generally reflect across three key dimensions: formal academic structures, informal professional and personal relationships, and the persistence of support across time and space.

Formal mechanisms YSU's mathematics department is cognizant of the fact that underrepresented minorities are more successful when they see people like themselves teaching, being cited, giving seminars, and leading the department. My first year at YSU was also the first year for new hire Dr. Alicia Prieto Langarica. My second year, Dr. Angela Spalsbury was elected to lead the department as chair. Women and mathematicians of color regularly visited the department and gave Friday seminars. For me, personally, Dr. Prieto Langarica recruited me to do undergraduate research, encouraging me and other female students to apply for the Nebraska Conference for Undergraduate Women in Mathematics. Both Dr. Spalsbury and Dr. Prieto Langarica acted as faculty advisors to the mathematical honorary Pi Mu Epsilon and AWM student chapter, and they sought out funding to host a regional Sonya Kovalevsky High School Mathematics Day. As leaders, these women worked to create an institutional framework which represented and supported all students.

Informal mechanisms The formal support structures were complemented by a critical informal support network. Social norms of respect, support, and reciprocity were reinforced through the actions of faculty and older students. I can cite many examples; for instance, Dr. Prieto Langarica formed a mathematics running group and through the group worked to get to know students better and encourage friendship, in addition to coursework and research. Participation in research and group projects, such as the COMAP Competition, formed genuine friendships bound together with joy and laughter and with scientific contribution as a consequence (to paraphrase Dr. Alicia Prieto Langarica). As young students we were given the agency to impact and contribute to Sonya Kovalevsky Day, invited to the table to brainstorm, design, and eventually lead the sessions. This act of building and creating something together built a community for us that would support the women in the department when life or work became more challenging.

Persistence across time and space Without a doubt, YSU's AWM Student Chapter and the surrounding community of women mathematicians and male allies contributed to my success during my undergraduate experience and my placement after. The supportive community of the AWM Student Chapter and of the math department itself calmed my anxieties and replaced them with ambition during my time there. However, this community stretches across time and place. It has and will continue to be a community I lean on for support and give support through. As I am no longer a student, but a friend of the department, I am happy to return to give academic talks and share in the mentoring process.

YSU's AWM Student Chapter has been a model for me to create new informal networks among women in my life, sometimes including YSU students in my new communities. Further, when impostor syndrome, self-doubt, and anxiety flare up in my life, I

lean on this community. Reflecting on the accomplished examples of my peers inspires and grounds me in my own personal and academic pursuits of making STEM and STEM research more inclusive to all. I have found lifelong fellowship in AWM and my mathematics community.

Final thoughts When I speak of my family's support of my academic work now, I silently include not only my Mom and Gram in my definition of family, but also the mathematicians in Youngstown State University's Association for Women in Mathematics.

Monica Busser is a proud Youngstown State University alumna who studied mathematics and women's studies. She earned her master's in mathematics from the University of Virginia. Currently she works as the program coordinator for a STEM outreach program for underrepresented minorities at Rensselaer Polytechnic Institute.

Alanis Chew is a proud graduate of Youngstown State University, where she received her bachelor of science in mathematics and bachelor of science in business administration. She is currently an Admin, Operations, and Research Analyst at a tech startup in stealth mode.

Jacquelyn Ehko is a graduate of Youngstown State University where she majored in integrated mathematics. She is currently a high school math teacher at Canfield Local Schools.

Ashley Orr is a graduate of Youngstown State University where she majored in mathematics and economics. She received her master's of philosophy in economics from the University of Oxford, funded by the Rhodes Scholarship. Currently, she is a PhD Student and NSF GRFP Fellow at Carnegie Mellon University.

12

Honoring Culture in Indigenous and Latinx Communities

Belin Tsinnajinnie with Sam Kennedy[1]

The gym in Santa Fe

Not too long ago, I returned to the gymnasium at Santa Fe Indian School where I played basketball as a boy. This gym was filled with memories from when parents from Indigenous communities all over northern New Mexico came to see their children play basketball. Back then, we had generations coming to support our teams, the concession stand had that familiar smell, and there was joy in the laughter and the teasing (depending on how the game progressed). The players felt empowered to do what the community wanted them to do in order to succeed.

This time, however, I was not in the gym to play basketball, but to attend the Julia Robinson Math Festival. The Math Festival had trained high school students to lead activities at individual tables filled with interesting mathematical puzzles and games. The idea was for them to host the Math Festival for middle school students at Santa Fe Indian School. Now the gym was filled with the same kind of energy that I had experienced as a boy, but this time focused on thought-provoking mathematics. We saw what it looked like when Native youth were given the authority to facilitate an event for their own communities in a social and cooperative atmosphere. Everyone could be their best selves, their whole selves, with their families right beside them. I saw a spark of what community-led mathematics could be, and where it could go.

I grew up in a rural locality in the desert. In our Diné (Navajo) language we call it Na' Neelzhiin, also known as Torreon, New Mexico. It is on the eastern edge of the Navajo reservation in the northwest portion of what we now call New Mexico. It is a sparse area with about a thousand or so residents, but you wouldn't know it driving through the region because the residences are really, really spread out. Learning mathematics in a rural setting involves challenges, including limited access to resources such as the internet. Even more, however, the structure for learning mathematics must be rooted in a community's heritage and culture.

[1] This chapter reflects Belin Tsinnajinne's experiences, written with help from Sam Kennedy.

Belin in Na' Neelzhiin.

I went to high school at Santa Fe Indian School (SFIS), a three-hour drive from Na' Neelzhiin. SFIS served students primarily from the nineteen Pueblo Nations across the state along with other Native nations. It provided a different kind of Indigenized center and learning experience.

Drawing from this rich heritage, I now teach a diverse group of students at Santa Fe Community College. Many come from Indigenous backgrounds. Many come from Latinx backgrounds. And many, like me, come from multiple backgrounds and have multifaceted identities. For me and many others, creating mathematical communities in, by, and for Indigenous and Latinx people requires a focus on the identities of these students and on the enrichment of the communities that have shaped their lives.

The diversity of our communities

I often think about the diversity within Indigenous and Latinx groups. My father is Diné and was raised in Na' Neelzhiin, and my mother is Filipina. Her parents immigrated from the Philippines to Hawaii. So I can see myself relating to the peoples in the Southwest as Indigenous people, but also to people whose parents are immigrants. And I'm hardly alone in having multiple identities.

David Austin, an Indigenous mathematician, serves as living proof of the strength of these cultures for a career in mathematics. As he describes it, "[a]s a member of the Choctaw nation who grew up in Oklahoma … I do know the challenge of working to become a professional mathematician while feeling like 'home' is far away. This is something that I'm able to share with the students, and I hope they hear in my story a message that it is possible to learn to live in two worlds at the same time, that there is great meaning to be found in accepting that challenge, and that there are resources to help [1]."

Learning and teaching mathematics in Indigenous and Latinx communities often takes a different form than it does elsewhere in the country. When we are teachers of record for students of a math course at Santa Fe Community College, we are also teachers of record

for their mothers, fathers, brothers, sisters, cousins, uncles, aunties, and nephews. At the same time, we are students of the mothers, fathers, elders, and other members within our community. We need to have an understanding that the experiences students have learning mathematics in our classrooms will have an impact on others they engage with nearby. In other words, there is a chance that students will carry a traumatic experience in a mathematics class with them as they engage with the youth. Thus, it is important to provide students with a mathematical learning experience that honors their identities and empowers them to provide a context for learning mathematics that they can then pass on. Teachers here are accountable for providing a mathematics education that's equitable, and we are responsible for seeing that people can have an experience that feels empowering, because empowering students empowers our whole community.

The mathematical assets inherent in our communities

As mathematicians who have undergone years of mathematical training, when we take on initiatives to develop mathematics in Indigenous and Latinx areas, there is a tendency to have the mindset that we are bringing the mathematics into communities, rather than seeing and appreciating the mathematics that is already here. When we have the idea that we are bringing mathematical insights to a group that does not have this knowledge, it can feel like we are "saviors."

But our real goal is to uplift people, to help them recognize their strengths and their mathematical knowledge—to come with the understanding that their culture is already mathematical and already rooted in rich mathematical traditions. This approach might look different, and it takes learning on our part to really unveil that perspective and understanding. The challenge is to bring that to light for the parents and help them realize that they possess mathematical knowledge and can serve as resources for their own children. For example, Indigenous communities in New Mexico have utilized patterns observed over the course of millennia in the night skies that informed agricultural practices sustaining the health, traditions, and well-being of their people. Pueblo, Diné, and Apache Nations in New Mexico have the knowledge and understanding that is essential to protect the land, waters, and living beings from encroaching efforts for resource extraction. When the region and those living and working there start viewing themselves as resources, we can move past the old "savior" model of math education and help people embrace their relationship with mathematical knowledge. We need to come to communities in a way that meaningfully engages their cultures and traditions, where people are not passive recipients of mathematics, but active authorities on their own firm cultural footing. Other mathematicians involved in the Alliance of Indigenous Math Circles (AIMC) agree.

The AIMC has encouraged and fostered the growth of mathematics in Indigenous communities through extracurricular activities where students investigate ideas collaboratively and experience the joy of mathematical discovery. The stories of the people involved in the organization create a narrative of Indigenous mathematics as it is and should be: run by, and run for, the Indigenous communities.

LaVerne Lomakema, a high school math teacher in Kearns Canyon, Arizona, and regional coordinator at AIMC, explains that "[m]ost Native communities are already economically disadvantaged; this creates stress on many communities. If students could

Photo Credit: Bob Klein, Alliance of Indigenous Math Circles.

AIMC Summer Math Campers huddle to debate a solution.

understand the role of mathematics in their communities and within mainstream society, their opportunities would be endless [1]." Craig Young, a middle school math teacher in Tuba City, Arizona, and regional coordinator of AIMC, observes that "[o]ur Navajo youth needed a program that empowered them in a traditional holistic approach that complemented their way of life and way of thinking. All indigenous communities have a history of complex mathematics and sciences through their cultures, and the Math Circles help our indigenous youth [1]." And Bob Klein and Tatiana Shubin add that "[i]n our experience, the flexibility of mind required to approach new grammars and vocabularies constitutes a true asset in terms of learning mathematics. Moreover, many indigenous languages reflect embedded philosophies that are radically different from the Western philosophies embedded in English. Being fluent in English and an indigenous language therefore magnifies that flexibility of mind, fostering the kind of creativity that leads to great mathematical discoveries [1]."

Making Indigenous and Latinx math flourish

Many organizations, groups, and associations of mathematicians and mathematics students from underrepresented backgrounds are building vibrant mathematical communities. But to me, two organizations which exemplify asset-based and community-centered learning philosophies, CEMELA and AIMC, have been transformative in my own mathematical career and in the creation of my mathematical communities.

The Center for the Mathematics Education of Latinos/as (CEMELA)[2] is a consortium

[2] CEMELA is a Center for Learning and Teaching sponsored by the National Science Foundation, grant number ESI-0424983. Any opinions, findings, and conclusions or recommendations expressed in this manuscript are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

of universities committed to improving mathematics education for Latinx students. At CEMELA, critical scholars in mathematics, language, culture, and teacher education work together to form asset-based approaches for mathematics education for Latinx students. This interdisciplinary approach aims to understand the interplay of mathematics education and the linguistic, cultural, and sociopolitical issues impacting Latinx communities. Embracing parents as resources in the education process, some CEMELA projects support after-school math clubs and family math nights which provide opportunities for Latinx students and their families to experience engaging mathematics that assumes their brilliance without the constraints of rigid school standards.

The Alliance of Indigenous Math Circles uses a "math circle" model of mathematics education, where mathematical knowledge is not viewed as something delivered from on high, but, rather, created and used and "wrangled with" by students themselves. AIMC provides math circle workshops for both students and teachers serving Native communities. AIMC workshops for students not only bring mathematics professors from academic institutions to facilitate math circle sessions for students but also elders and experts from within Indigenous communities to facilitate activities to support Native cultural learnings and identities. AIMC teacher workshops provide opportunities for educators to engage in math activities that are offered in math circles and at math festivals. These math circles and the family math nights run by CEMELA both work to bring the entire community together to do mathematics. They engage the whole student, their upbringing, their identities, and their cultural histories.

Conclusion: family as community

Many people in mathematics communities are interested in equitable educational opportunities. These include math educators, in-service teachers, mathematicians, teacher educators, and policymakers. But we now have effective models that involve families and communities in initiatives that advance mathematics. Perhaps the next step considers how we can include these families and communities in policy and curricular decisions. These incremental steps will give Indigenous and Latinx communities an increasing opportunity to have agency in decisions that affect their children and neighborhoods. In turn, this inclusive combination of ideas and voices will lead to stronger and more equitable mathematics educational opportunities.

Reference

[1] Klein, B., Shubin, T. (2019). Building the Alliance of Indigenous Math Circles. *Notices of the American Mathematical Society*. 66(4): 540–546.

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13

The Duluth Undergraduate Research Program
A Community of Peers

Joseph A. Gallian

Preface

In his 2016 candidate statement for the office of Vice President of the American Mathematical Society, David Jerison wrote "I believe that mathematics depends on social connections. Aspiring researchers and teachers need to see how we create and use mathematics and how they can participate in this enterprise." The Duluth REU is designed to provide a community environment in which undergraduates who aspire to be research mathematicians can do just that.

Evolution of the program

The Duluth REU community began in 1979 when I received an NSF grant to work with three undergraduates on research over the summer. Little did I know then that over the next four decades that program would develop into a community of 250 plus peers that continues to the present day. By 1989 the program had grown to seven undergraduates, two program alumni graduate students, and one program alumnus who had obtained a PhD. A new era began in 1993 when the program expanded to include two program alumni graduate students as advisers (counselors), three alumni undergraduate visitors, and three alumni with PhDs as visitors. Rather than having the program exclusively for undergraduates, I wanted it to be a "Tanglewood of mathematics"—a vertically integrated program where highly talented mathematicians of all ages can interact. Indeed, my goal was to have a community of peers consisting of a mix of undergraduates and alumni graduate students and PhDs. By 1997 there were eight undergraduates, seven alumni graduate students, and four alumni PhDs. The number of participants would gradually grow to nine first-time undergraduates and twenty-or-so graduate student and PhD visitors with an occasional visitor who was not an alumnus. Many visitors return for multiple summers.

One alum has participated for more than thirty years, another for more than twenty years, five others have returned for ten or more years, and more than 25 have visited for between five and nine years. Despite the wide differences in ages, repeated visits by many program alumni foster a sense of community among the participants. Because of their experience and knowledge of the program, I value the opinions of the graduate students who serve as counselors and visiting alumni on the operation of the program. They interact with the new participants mathematically and socially. The most important outcome of the visits by former participants is network building. Many participants in the program from different summers have developed long-term professional relationships and friendships.

Structure

The ten-week programs are loosely structured. Each student is given his or her own combinatorics or number theory problem together with an article or two as resource material. On Mondays and Tuesdays the undergraduate participants give talks on their progress from the previous week. The talks give all participants an opportunity to assess progress, raise questions, make suggestions, and identify difficulties. Preparing their talks helps the students organize their thinking and their research. It also serves as good preparation for writing their final papers and for presenting their results at conferences after the program is over. To build community further, we have a group lunch on campus on the two days we have talks.

The housing arrangements are a critical part of the program structure. UMD has attractive on-campus furnished apartments with living rooms, kitchens, and bathrooms. People move freely among a block of contiguous apartments as though they share one very large house. The living arrangements and the mix of old and new participants foster

Photo Credit: Joe Gallian.

Lake Superior boulder photo shoot.

interaction and collaboration, two key components to establishing a sense of community in the program. Since there are no instructional lectures and few formal meetings, the participants spend most of their time in the apartments.

Students write up their results as they go rather than near the end of the program. Their papers are written in a style suitable for submission to a research journal. After the manuscripts are read by several participants, the students incorporate the suggestions and comments and submit the revision for publication. Typically, this process is completed by the end of the summer program or shortly thereafter. Of course, there are some who do not end up with a publishable paper. In some cases the research did not warrant publication and in other cases the research was publication-worthy but the student was not willing to do the work required to get it published.

The ten-week length of the Duluth REU offers many advantages over the typical REUs that run eight weeks. In cases where a student's initial problem was not a good fit, there is still enough time to have success with a new one. The same is true in cases where a student finishes the initial problem quickly. In fact, it is common for a student to get more than one publication in one summer program. The record is five, all published in well-regarded journals, in 2009 by Yufei Zhao.

Field trips

Beginning in the early years of the REU, I strove to build community in multiple ways. Beyond the natural bonding that takes place when young people live and work together, organized field trips are one way that they play together. Participants often cite these as an important aspect of the REU experience. When program alumni return for a week visit, the first thing they ask is "What is the field trip this week?" Among the field trips are alpine sliding, white water rafting, biking, trampolining, and visits to the beautiful parks in the area. In some years the participants have organized a weekend camping trip to a state park or to the boundary waters canoeing area. All participants have access to university cars at no cost. This makes it convenient for them to see movies, shop, eat out, and explore the area. Occasionally, we have lunch at a restaurant as part of the field trip. The field trips and group lunches foster a sense of camaraderie among the participants.

The most memorable field trip each year is alpine sliding at Lutsen Mountain. Riders are not buckled in and they control their speed from the top to the bottom of the two side-by-side half-mile tracks. Despite signs saying not to race, many people do. Every year there is a group photo of people displaying the cuts and scrapes they received when their sleds flew off the track.

In mid-summer there is a field trip to nearby Gooseberry Falls. Following a picnic-style lunch and hike, we swim in the basin of a magnificent waterfall. There is always a group photo taken on one particular large boulder in Lake Superior.

Program traditions

As is always the case for long-standing programs, many traditions have evolved. In the first week we take a walk on the boardwalk that hugs spectacular Lake Superior near the shipping canal in downtown Duluth. One stop is the iconic "lift bridge" that remains

Photo Credit: Joe Gallian.

Alpine sliding.

horizontal while it lifts vertically to allow oceangoing vessels and Great Lakes freighters to enter the harbor. Another stop on the boardwalk is the malt shoppe that features delicious ice cream treats. Because of its proximity to the campus, trips to the malt shoppe throughout the summer are common.

A short drive along the scenic north shore of Lake Superior is Betty's Pies restaurant whose menu includes blackberry peach crunch pie, strawberry rhubarb pie, and five layer chocolate pie. Trips to Betty's often occur when new visitors arrive. One tradition is the "Pigs Trough Challenge" of eating half a pie with one whole banana, four scoops of ice cream, whipped cream, and mounds of toppings in fifteen minutes. Those who accomplish this formidable feat win a free Betty's pies t-shirt. Every year a few program participants succeed. Duluthian REU participant Levent Alpoge finished the challenge in a record time of 3:44 on his first attempt and broke his own record the next year with a time of 2:55.

Evenings provide another opportunity for everyone to engage in community activities by sharing meals, playing games, and watching movies. "Gluck" and "Resistance" are two popular games. In recent years the participants have frequented escape rooms in downtown Duluth and have held karaoke nights at the apartments. The students sometimes break out into songs on hiking and biking field trips.

When the number of talks by participants on Mondays and Tuesdays grew to four per day, we decided that it would be good to have a "half-time" 20–30 minute break each day. These feature a fun game such as mathematical charades, Pictionary, or a math-based quiz. One annual quiz asks for the LaTeX code for esoteric expressions. Another involves identifying well-known mathematicians from their photographs or providing their first names. In one quiz, participants are asked to identify the authors of famous theorems; in another they must identify quotes from famous mathematicians. The names of the quiz winners dating back to 2010 are kept on a "Half-Time Hall of Fame" white board in the room where the talks are given.

The Duluth REU has had a program t-shirt for decades. The front features mathematical images related to the research problems for that summer. The back has an image of the Duluth aerial lift bridge surmounting a list of the participants from all years. Some t-shirts include a quote at the bottom that was a catch phrase that year. The students choose the color and quote.

In the last week of the program we have "Beatles night," which started as an evening dinner at my home followed by my favorite Beatles videos with commentary by me. Eventually, that evolved into a variety of video clips featuring Duluth REU participants who have appeared on national television. Among them are two participants who were on "Who Wants to be a Millionaire" (one won $500,000), two who were in the championship round of the National Spelling Bee (one finished first and the other third), three on Jeopardy (two advanced to a second day), one who was on the vintage game show "To Tell the Truth," one on "The Million Second Quiz" (who lost on a tie-breaker in the championship round), and one who was on a PBS program playing violin on stage at Lincoln Center with Itzhak Perlman and a third violinist.

In some years the last week of the program has included a talent show that features a variety of performances. In one show a student performed his own piano compositions, there was a group rendition of the songs "A simple group of order two" and "Hey Jude," and one participant offered a fashion show with creations she had knitted over the summer.

Because Duluth is a wonderful tourist destination in the summer, throughout its four decades many parents and friends of participants have visited the program.

A tradition that extends the community atmosphere of the summer program to the academic year is when program participants share rooms, have meals together, and attend

Photo Credit: Joe Gallian.

Gooseberry Falls.

talks and social events as a group at the annual January Joint Math Meetings. People always take notice when a contingent of "Duluthians" show up *en masse* at a paper session.

By far, the most important tradition is the return of program alumni for visits of a week or more.

Beyond the summer REU

Follow-through is a crucial aspect of the program. Occasionally, some students leave Duluth before their papers have been submitted for publication. The graduate student advisers and I work with them to ensure that the papers are written up in a form suitable for a journal. Many months later, there are the inevitable referees' reports recommending revisions that the students must make. When papers are not accepted by a journal, I provide advice about what to do next.

The community aspect of the Duluth REU often extends to graduate school. When Duluth participants make visits to graduate schools, program alumni often act as hosts and provide "inside information" about the advantages and disadvantages of the department. Besides the networking benefits of being part of the Duluth REU community of peers, many research papers have been jointly authored by participants subsequent to their time in Duluth. For instance, five program participants have coauthored papers with Fields Medalist program alumnus Manjul Bhargava. Moreover, three of Bhargava's PhD students were Duluth REU participants (all three are women) and two more are his current PhD students. Duluth alumnus and MIT professor Zhao's first three PhD students are from the Duluth REU.

Program benefits

The development of research ability is the explicit purpose of NSF REUs. Taking classes and participating in math competitions provide students with little or no experience with the research process. Besides learning firsthand the nature of mathematical research, outcomes of participation in the program include: increased self-confidence and self-esteem; motivation to pursue a PhD degree; enhanced chances of being admitted to their first choice for graduate school and receiving a fellowship; and joining a network of people who will likely be active members of the mathematics community.

The most important contribution the Duluth program makes to the profession is the training of future generations of mathematicians who will foster undergraduate research when they become professionals. Indeed, three participants from the program have been directors of their own REU programs, three more served as a faculty adviser in REUs, another was part of a four-school collaboration to involve undergraduates at Historically Black Colleges and Universities in research, several have been advisers in MIT's Summer Program in Undergraduate Research and in MIT's Research Science Institute for high school students, one directs summer undergraduate research programs at Duke, two supervised students in research programs as graduate students, and two have supervised undergraduates in summer programs at the Center for Communications Research at Princeton and La Jolla.

A wonderful example of the benefits stemming from the REU is the collaboration among three alumni who were still undergraduates and Yufei Zhao in the spring of 2018.

That collaboration resulted in the solution of a challenging 2001 conjecture of Rutgers mathematician Jeff Kahn that many experienced mathematicians had worked on without success. The same four coauthored a paper in 2019 with Stanford professor and Duluth REU alumnus Jacob Fox on a multidimensional variant of results by Ben Green and by Green and Terry Tao.

Testimonials

I conclude with comments from four recent Duluth REU community participants taken from their personal statements in their applications for graduate fellowships. The comments are an affirmation of AMS Vice President Jerison's statement about the importance of social connections in mathematics mentioned at the beginning of this article.

> *There is no question for me that the summers I spent in Duluth were the two best summers of my life so far. While the participants usually work on their problems individually, what made the REU so special for me was the interactions I had with the other students, advisors, visitors, and, of course, Professor Gallian himself, both on a professional and a personal level. We exchanged ideas during weekly presentations, shared our favorite theorems on road trips, challenged each other to Olympiad problems during lunch, and played some of the most challenging and fun games I know every night. There were also many alumni visitors, who generously volunteered their time to talk about math with us, chip in on the problems we worked on, and tell us about their math careers. I got a lot out of the Duluth REU: I learned math, got an idea of what mathematical research is like, met interesting people, and had a good time. But for me (and many others), the REU was even more than that: for the first time since moving to the United States for college, I felt a sense of community and belonging. It was a clear turning point in my life.*

> *This research was dramatically different in style and content from my earlier project [done at MIT]. I worked on this problem alone, but in a setting full of mathematical ideas and camaraderie. At the Duluth REU, all of the students as well as a number of visitors discussed each other's problems together and contributed to a strong sense of community, and I made a number of friends there who I continue to work with in both the mathematical and personal spheres. I also learned a great deal about the problems of my fellow students, which gave me a lot of mathematical insight and showed me a wide variety of approaches to research that mathematicians can take.*

> *This past summer, I also returned to the Duluth REU as a visitor for three weeks. There I was again able to use my past experiences and abilities to help the students with many of the parts of the program, including giving feedback on their talks and papers, and looking over their research itself. Again, the program included both students that I knew from previous mathematical endeavors and students that I did not. I enjoyed this experience a lot, partially because of how much the Duluth program feels like a community, due to the fact that many students from previous years (such as me) return as visitors or advisers. I liked having the chance to contribute to that environment as more than simply a student.*

A year ago I hardly could have dreamed of the exciting opportunities I've been given. My time at Duluth and the network of Duluthians have been (and continue to be) truly invaluable.

Joseph Gallian has been at the University of Minnesota Duluth since 1972. He is a former President of the Mathematical Association of America.

II

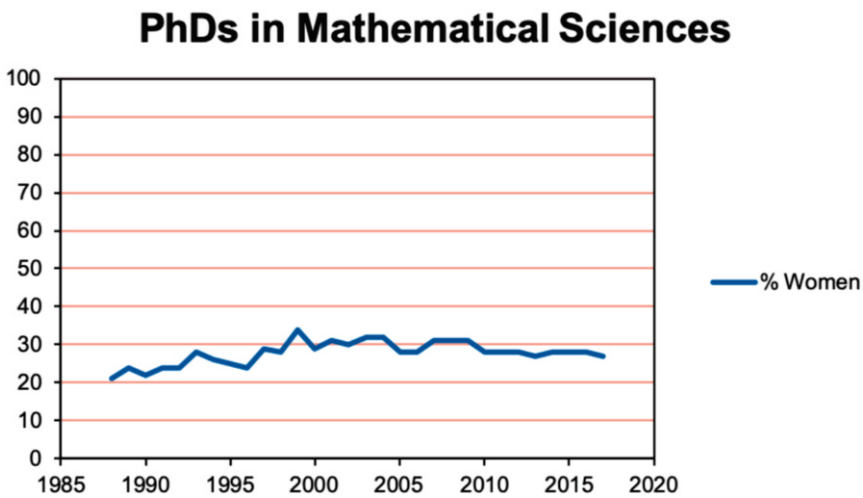
Communities for Graduate Students and Professional Mathematicians

14

Women in Numbers
a Research Community

Michelle Manes

When I lament the pathetically few women in tenure-stream positions at top universities, I often hear some version of the following: "There are so many women in graduate school now … 30% of the PhDs go to women. So it's just a matter of time until that trickles up into the ranks of the faculty." The truth is much more grim: That 30% statistic is a bit overstated, and the data show that the percentage of women earning PhDs in mathematics has been essentially flat for more than thirty years. If the "trickle up" idea had any validity, we would have several women in faculty positions at all of the major research universities by now. We don't. When you work in an inequitable and discriminatory system, equity and inclusion don't just happen. The story of Women in Numbers (WIN) is a story of actively working to increase equity and inclusion. The quotes that start each section come from participants in WIN workshops on their anonymous evaluations.



Percentage of PhDs awarded to women each year in the mathematical sciences. Data compiled from AMS "Statistics on Women Mathematicians" [1,2,3,4].

How it all began

I go through phases where I seriously consider leaving academia. I never think that I am doing so well, and I often feel isolated and like my presence or absence from the community doesn't matter. But right now I feel really good.

The Women in Numbers origin story goes something like this: In the mid-2000s, Kristin Lauter, Rachel Pries, and Renate Scheidler found themselves at (yet another) prestigious international number theory conference, complaining to each other that (once again) there were no women among the plenary speakers. Between the three of them, they knew lots of women doing high-quality research in number theory, but somehow these women weren't getting the recognition they deserved. With just a few exceptions, women doing research in number theory were not giving talks at major research conferences and weren't recognized for their contributions to the field.

The three women hatched an idea: a conference that would build a network of women doing research in number theory, that would highlight the research contributions of women in number theory, and that would broaden the research programs of women working in number theory, especially pre-tenure. After discussing the idea with several friends and mentors, they decided to propose a workshop at the Banff International Research Station (BIRS). Their proposal for "WIN: Women in Numbers" explicitly stated their ultimate goals:

Although the number of female number theorists has grown over the past fifteen years, women remain virtually invisible at high-profile conferences and are largely excluded from elite international workshops in number theory. Moreover, there are still few tenured female number theorists at the top research universities … ***The goal of our workshop is to increase the number of active female researchers in number theory.*** *(emphasis added)*

Photo credit: Katherine E. Stange.

The three founders of WIN, together again at WIN3 (from left) Kristin Lauter, Renate Scheidler, and Rachel Pries.

The proposal was accepted by BIRS, and the first WIN conference took place from November 2–7, 2008.

The workshops

This is a fantastic opportunity to work with other mathematicians on great mathematics and in a unique social environment that helps me feel a part of the mathematical community. It was good to have such a vertical range of female mathematicians around.

For the first WIN workshop, the organizers invited project leaders and a few participants, and they had an application process to fill the remaining slots. A total of forty-one number theorists attended the workshop: fifteen senior and mid-level faculty, sixteen junior faculty and postdocs, and ten graduate students.

Before the workshop, the fifteen group leaders designed research projects for the groups to tackle during the workshop, and each participant was assigned to one of eight project groups. During the workshop, each group leader gave a 45-minute talk introducing the topic of their group's project to the rest of the participants. During the afternoons, the groups worked on their research projects. On the final day, each group presented a progress report: What had their group accomplished? What did they still hope to do? And what was their plan for finishing the work? To date, there have been six WIN and WIN–Europe (WINE) conferences. Each WIN conference is unique. The organizers tweak the format of the conference based on participant evaluations along with their own ideas about what could be improved. Over the years, the workshops have had fewer, shorter talks with a lot more time devoted to the group work. Some have incorporated talks not related to any project group. Some have included more formal panels in which senior women share their experiences and offer career advice. What makes these conferences really different from other programs for women in mathematics is that the focus is always squarely on the research and on building collaborations. Conversations about career trajectories, job applications—and yes, two-body problems and babies—happen naturally over meals or in the evenings. The focus of the workshop, however, is always on the mathematics.

The network

I've received many pieces of good advice in the short time here about topics such as meeting people in my research area, establishing a research program, giving talks / contacting people about my research, etc. I think I will now have several people to contact in the future for career advice, and I think this is invaluable.

During the first WIN workshop, the organizers made explicit some expectations, and put out a call to build the community:

This is not a one-time workshop; there will be more. They asked for volunteers to organize the second WIN conference a few years down the line, and Chantal David, Matilde Lalín, and Michelle Manes volunteered.

There will be a Proceedings volume. They asked for volunteers to help edit the volume, and Alina Cojocaru took on that role.

Photo credit: Banff International Research Station.

Group photo from the first WIN workshop in 2008, "WIN: Women in Numbers (08w5112)," taken at Banff International Research Station in Banff, Alberta.

This isn't just about conferences; we're building a network. Katherine Stange volunteered to create and maintain the website for this new network, and Michelle Manes volunteered to create and maintain a listserv. Several volunteers planned to organize special sessions at upcoming AMS Sectional and National meetings.

The organizers took the incredible step of turning over leadership to an entirely different group of people, trusting them to continue and to build on the WIN model. The trust fall paid off in a big way: To date 21 different people have worked to organize WIN and WINE conferences, 66 women have led at least one project group at a WIN or WINE conference, and 172 distinct participants have attended one of the conferences. (These numbers do not include WINE3, WIN5, or any other future conferences.) The WIN community continues to grow and thrive; it doesn't depend on the energy and time of the three founders. Kristin, Rachel, and Renate continue to organize some of the WIN conferences and to lead projects at many of them. But the community has become self-sustaining.

The Proceedings volume was especially important in working towards the stated goals of the first WIN workshop: Having a venue to publish their work and a timeline for completion encouraged the groups to continue collaborating and to finish the projects after the workshop ended. Seven of the eight working groups from the first WIN workshop had papers accepted to the peer-reviewed volume, and some groups contributed more than one paper.

Near the deadline for submissions, several groups happened to post their papers on arXiv on the same day. A colleague saw me in the hallway and asked, "Hey, a bunch of papers went up on arXiv where all of the authors are women. What's up with that?" Of course, every single day several articles are posted authored only by men, and that passes without comment. It was clear to me in that moment that the WIN workshop had already increased the visibility of women doing number theory and their research. Each subsequent workshop has resulted in a peer-reviewed Proceedings volume that contains new research from the project groups, survey papers by the project leaders, and contributed papers by other members of the WIN community [8, 9, 6, 10, 7, 9].

Just as the organizers hoped, the network has grown beyond the workshops: The website (https://womeninnumbertheory.org/) includes a directory of women who do research in number theory, a tremendous resource for conference organizers looking to diversify their slate of speakers. Members of the WIN community use the listserv to share opportunities (e.g., conferences, job postings, and funding opportunities) and to celebrate each other's successes. WIN workshops happen about once every three years, and only 42 people can attend any given workshop. Even if the workshops are held at larger facilities, the logistics of organizing project groups and the demands on more senior women working in number theory limit how often the research collaboration conferences can reasonably occur. The special sessions at AMS Sectional and National meetings keep the community going between WIN workshops, allow us to welcome all women working in number theory into the WIN community (even those who have never attended a WIN workshop), connect WIN to the larger mathematical community, and further the goal of increasing the visibility of women and their research.

More recently, a Steering Committee comprised of organizers of past WIN and WINE conferences was established to keep the community active and organized. Kristin Lauter, who serves on Steering Committees for other conference series, initiated the idea as a mechanism for an ongoing long-term conference series. The Steering Committee makes strategic decisions for the community, recruits conference organizers, and keeps track of funds for the community. The Steering Committee first met during the WIN3 conference, and they continue with quarterly meetings online.

Perhaps most important, WIN has become a network in which the members support each other personally and professionally: suggesting women they know for opportunities like plenary talks at conferences and positions on editorial boards, helping each other with navigating the job market and writing grant proposals, and always rooting for each other to succeed. When someone in WIN encounters career challenges, difficult decisions, or issues they are uncomfortable discussing with other colleagues (usually men), the WIN network is there. For example, one woman received an NSF grant shortly before giving birth to her first baby. She was struggling with what to do about her summer salary, knowing that she could use the money but also that she might not be doing as much mathematics over the summer as she had originally anticipated. She wasn't ready to disclose information about her pregnancy to her institution or to NSF, but she wanted to talk to someone about these questions. I didn't have a good answer, but I did know three members of the WIN community who had held NSF grants at around the same time they had newborn babies, so I put her in touch with the right people.

Outcomes

This is an awesome and useful format, and it was especially useful to meet so many women in the field. I was afraid the atmosphere might be depressing (I find that it often is when women meet up and complain about the difficulties or disadvantages they face), but it was the contrary, it was helpful and encouraging!

There is no doubt that the WIN network is successful by nearly every measure. Significant new research comes out of each workshop. Several of the WIN groups have developed long-term collaborations that have produced an impressive body of research. Participant surveys offer opportunities for reflection on both Research Groups and Conference Experiences. The overwhelmingly positive responses underscore the success of the WIN research groups and the conference itself. Surveys show participants find WIN research groups foster collaboration while working on exciting projects during the conference and establish successful ongoing connections once scholars return to their home institutions. Perhaps the most important measure harkens back to the original goal of the first WIN workshop: "The goal of our workshop is to increase the number of active female researchers in number theory." The number of women speaking at and participating in prestigious international number theory conferences has increased, though the numbers may be too small to deem significant.

Since 2008, at least sixteen women working in number theory have been hired into tenure-stream jobs at major research universities; all of the women in this count are WIN alumnae. I am certainly not suggesting these women got their jobs because of their participation in WIN, that they wouldn't have been so successful if not for WIN, or that there is any causal relationship at play. But these women all found value in the WIN community, and I think that speaks volumes.

Challenges

This workshop improved my confidence about how well a collaboration can go. I'm worried, though, about how well this will carry over beyond the world of WIN. (This

	Before WIN1			
Algebraische Zahlentheorie	2005: 1/19	2011: 3/19	2014: 5/19	2018: 4/20
Algorithmic Number Theory Symposium (invited talks)	2006: 0/5	2012: 1/5	2016: 2/5	2018: 2/5
Canadian Number Theory Association (plenary talks)	2006: 0/15	2012: 1/10	2014: 2/10	2018: 1/9
Explicit Methods in Number Theory	2005: 1/30	2013: 4/24	2015: 4/15	2018: 6/26
Journees Arithmetiques (plenary talks)	2007: 0/12	2015: 3/12	2017: 3/10	2019: 3/11

Women at major number theory conferences.

workshop gave me a taste of what is possible, but there's still the same dysfunctional community out there …)

The WIN community is certainly not perfect. We can't fix sexism by focusing on women, and it's not clear that WIN has (or can have) a significant impact on the men in our field. In fact, anecdotal evidence suggests that men discount the collaborative work at WIN conferences, saying it's hard to know how much credit to give any individual contributor on a multi-author paper, and that young researchers might be better off pushing forward their own research agendas.

Maintaining the WIN community is work, and that work predominantly falls on mid-career women. This group benefitted from WIN early in their careers and feels a responsibility to maintain the community and pay it forward to the next cohort. But organizing major conferences takes time and energy that could be devoted to other things. Designing and leading project groups is also a significant commitment. The three-year time frame means that many of the WIN project leaders find themselves in a cycle of developing, leading, and bringing to completion a WIN project just in time to develop another one for the next WIN conference. It is probably not true that WIN projects detract from early career researchers developing their research programs, but it certainly is true for the mid-career women involved in WIN leadership.

And we can't ignore the issues of intersectionality. There is no denying that WIN conferences are populated almost exclusively by white women. We have tried to increase diversity at WIN by advertising the workshops more broadly and partnering with organizations that support groups under-represented in mathematics—groups like the National Association of Mathematicians (NAM) and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS)—to spread the word. The most recent WIN workshop was also the most diverse, but diversity is not the same as inclusion, and we have to work a lot harder to support women of color in our community. Mathematician Piper H. writes, "[Men] aren't the only ones who can make me feel unsafe … Really we need to all be asking ourselves how to make others feel like they belong. All of us need to be committed to reaching out to those we could easily be talking over. We should all be asking ourselves how we are showing marginalized people that they are accepted and safe."

Furthermore, the language in early grant proposals, the language in this chapter, and even the name "Women in Numbers" can feel exclusionary to trans and non-binary mathematicians. Certainly they would be welcome at any WIN conference, but that may not be clear from conference websites and application materials. We continue to talk about the importance of language and how it does (or doesn't) reflect the values of the WIN community. We're not quite ready to change the name to "anyone but cis men in number theory," but we're open to suggestions.

The legacy

I think the whole math community needs to take up the WIN concept so that all women can get involved in a WIN-like group in their area of math.

The WIN conferences were so clearly successful that, once word got out, they were sure to be emulated. More and more groups created research collaboration conferences

for women (RCCWs) in various fields of mathematics along with research networks to keep the communities going long term. The AWM felt it was worth doing some serious research: Is this a model that just feels good, or do these RCCWs really impact the women who participate in them? Do they impact the fields? Do they impact the broader mathematics community?

The AWM won an NSF ADVANCE grant (HRD-1500481) to support the creation of more RCCWs and research networks for women in order to study the outcomes of these conferences over many years. At the time of this chapter, there are nineteen research networks listed on the AWM ADVANCE website (awmadvance.org/), and plans for several more are underway. Erin Leahey, professor of Sociology at the University of Arizona, is funded to develop surveys, evaluate the results, and conduct a study on the effects on the mathematical careers of the women participating in the grant activities.

Outcomes so far are promising. Examining data for eighty participants who have attended more than one workshop, Leahey has found that the workshops are effective in bolstering participants' careers: In the time between their first workshop and their most recent workshop, the percentage of women who held leadership positions in a national or international mathematical society or association increased, the number of speaking roles has increased, participants have become more collaborative, and the number of grants that RCCW participants were awarded increased. Anecdotally, since the advent of the RCCW model, we have seen a noticeable increase in the number of tenure-stream women faculty at research universities, an increase in the number of conferences and special sessions which have at least fifty percent women speakers, and an increase in the percentage of women speakers at major international research conferences and in prestigious seminar series.

Conclusion?

This is the best workshop I've ever attended! It was very productive and very fun.

It's hard to know how to conclude this chapter, since the story of WIN goes on. By the time this volume appears, there will have been at least two more conferences, lots of new research, and new members of the community. There's still a lot more for us to work towards: Women are dramatically under-represented on editorial boards, especially for the top journals. Women are gaining faculty positions at major research universities, but we are not even close to the 30% threshold that studies show alleviates the effects of being in the minority in a community. And there are virtually no women in number theory or in other fields at the top five mathematics programs in the country.

Change happens too slowly, but WIN and other research networks for women are advancing mathematics, both by creating new research and by creating positive change in the careers of women in the field.

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15

The Women and Mathematics Program at the IAS

Michelle Huguenin, Dusa McDuff, Margaret Readdy, and Karen Uhlenbeck

A brief history

The Women and Mathematics (WAM) program at the Institute for Advanced Study (IAS) began in 1993 with a small NSF-funded workshop at MSRI that was an offshoot of the summer program at Park City. As Karen Uhlenbeck recalls,

> *I do not see the (WAM) program as having a "big picture." It grew and adapted. It was started because both women mathematicians and several institutions were concerned that in the 1990's, despite changes in admission and hiring practices, the numbers of women in mathematics did not grow as hoped and expected …*
>
> *My participation in the founding of the Park City Mathematics Institute (PCMI) was partially motivated by the fact that I had benefited from meeting other women at conferences, and I thought this would happen at Park City. During the first few years, the numbers of women attendees at PCMI were dismally small, except for the cadre of high school teachers. The NSF noticed and put some pressure on us. Also, my peer group of women professors at this time noticed that we were often the youngest women in our departments; the numbers of women entering the profession were still very small. We felt it was time we paid back some of the help we had received in succeeding. At that time, several (but certainly not all) institutions were concerned about the lack of women. Not everybody agreed that having a woman's program was the answer.*

This first workshop was brilliantly organized on short notice by Antonella Grassi of the Mathematical Sciences Research Institute (MSRI), who was a postdoc at the time. Participants found it unexpectedly inspiring and invigorating. The question became: How can we sustain this energy?

Phillip Griffiths, then Director of the Institute for Advanced Study (IAS), offered to take over the administrative responsibility for PCMI. As part of this arrangement, Griffiths

approached Uhlenbeck, offering funding, housing, classrooms, and administrative support at the Institute for the workshop for women. Uhlenbeck then approached her friend Chuu-Lian Terng (at that time President of AWM) for help organizing it. They did co-organize together for many years, with very significant administrative help from Anne Humes at IAS.

> *That women were underrepresented in mathematics, especially at the highest levels, was obvious; before the Women and Mathematics program began, the number of female postdocs in the Institute's School of Math each year could usually be counted on one hand. The Institute had been in discussions about assuming responsibility for the Park City Mathematics Institute (PCMI) when Karen Uhlenbeck had the inspired idea of inviting groups of women mathematicians to Park City for two weeks of intensive mathematical talks on the PCMI research theme prior to the summer sessions. The objective would be to help them prepare for the formal program; there would be no talks on the challenges for women in the profession, which could be addressed informally outside of the sessions, but rather a laser focus on mathematical research. Coupling PCMI with WAM in this way struck me as a brilliant concept, and I was pleased to be able to provide administrative support and modest discretionary funding for the first year; and later, when Princeton University also became involved through the leadership of Alice Chang, to help bring in additional funding.*
>
> —Phillip Griffiths, former IAS Director

One of the guiding principles of WAM has been to involve as many senior women as possible. Over the years this help has included reading application files, coordinating visits from senior faculty to the program, and organizing panel discussions on a wide variety of topics. Many people contributed at different times, but Nancy Hingston and Antonella Grassi have remained dedicated to WAM throughout its existence.

Photo Credit: Andrea Kane, Institute for Advanced Study.

Past and present Women and Mathematics committee members. First row (from left) Alice Chang, Lisa Traynor, Chuu-Lian Terng, Christine Taylor, Michelle Huguenin. Back row: (from left) Margaret Readdy, Antonella Grassi, Nancy Hingston, Dusa McDuff, Karen Uhlenbeck.

In time, this group coalesced into a local committee formed by women faculty at colleges and universities near Princeton. The committee is now one of the essential elements in the running of the program. It meets twice a year, discusses and decides on the main theme of the programs, chooses participants, and suggests workshop topics and lecturers. When possible, its members also attend the program as senior mentors.

In its beginnings, the program was simply part of the Park City Institute, supported by both NSF funds and the generosity of IAS and its donors, which included the Starr Foundation and the Geraldine Dodge Foundation. Gradually WAM grew more independent of PCMI, partly because it was difficult for women to commit to attending both programs. As a sign of further independence, WAM applied for and obtained its own NSF grant.

When Shirley Tilghman became President of Princeton University, as part of her concern for the status of women at Princeton University, Princeton began to sponsor the program with the IAS and participants spent a day at the Princeton University Mathematics Department.

At present, the majority of funding comes from the NSF with additional support from IAS, Lisa Simonyi, and Princeton University. An important factor in its longevity is that throughout its existence all three IAS directors, as well as several IAS mathematics faculty, have been staunch supporters.

Women doing math together

The main aim of the program is to prepare women to enter the world of research mathematics. As an unexpected bonus, it created an environment for women to do mathematics together. In the early 1990s this was a fairly radical idea, partly because many women had internalized the prevailing prejudice against female mathematicians. Being among a large group of female mathematicians is still a revealing and refreshing experience for many. Here are some reactions from some current members of the WAM committee.

> *I was somewhat ambivalent about the "all female" aspect of the program, but I was easily won over when I saw how beautifully it worked, and the positive and lasting impact it had on so many.*
>
> —Nancy Hingston, long-time member of the WAM Committee

> *One year while I was still an undergraduate (at Princeton), the WAM program came to Fine Hall for a day. I saw a talk given there by a distinguished speaker invited by WAM. I was a math major, and I loved math "best" of all the subjects I was studying, but I had been preparing to go to medical school. During the talk, I looked around the room, filled with women. I remember thinking, "Here we all are, thinking with our individual brains about the same abstract concepts, which we can't see in any literal sense, but are all thinking about together." I felt at that moment like I was part of a community, and I let go of applying to medical school, and fully accepted my choice that I would become a mathematician.* —Lillian Pierce

> *My first impression was a realization that I could "let my guard down" being surrounded only by women. That this was a completely different social and professional dynamic than being with colleagues of both genders. This was quite a revealing experience for*

me. It wasn't clear if it was a better or worse environment for learning, but I certainly felt much more relaxed and that I could open up to faculty and students in ways that I usually don't. —Lisa Carbone

These reflections capture the powerful effect of the atmosphere of WAM. The lectures and colloquia are open to all, and a few non-participants do attend sometimes, especially the colloquia. However, the working groups, seminars, and most of the dinners are for participants only.

The range of participants

One special feature of WAM is that it is "vertically integrated"—it involves women at all stages of their careers, from undergraduates who are not yet sure of their future career paths, through graduate students at various stages, to postdocs and faculty at all levels. The goal is for the participants to meet successful role models at all levels, and to see the successful transition from one level to the next. The participants learn from one another professionally and personally, and all get a sense that the field is progressing and renewing itself with new members and professional contacts. The precise mix changes from year to year in response to the pool of applicants, which largely depends on that year's subject area. The current aim is to have sixty participants, roughly fifteen advanced undergraduates, thirty graduate students split between beginning and advanced, and fifteen postdocs and junior/senior faculty. Since around fifteen percent of participants return to WAM in a different role at different stages of their careers, this makes it possible for WAM to build a real community with many connections to mathematicians working in the US and abroad. WAM is now building on this strength with its Ambassador program, described in detail below. The program obviously affects participants at each career stage differently, but it does affect everyone involved, with the generations educating each other through the power of tiered mentoring.

The biggest lesson I learned is that the senior women benefited even more than the participants. It is quite an experience to lecture to a room full of women and to follow the women you meet at WAM as they progress through their careers. It gives insight into your own life. —Karen Uhlenbeck

Of all the math conferences I have been to, the Women and Mathematics program was probably the most influential on my career path. I attended WAM the summer before starting graduate school and was a bit nervous about what I was getting myself into. Coming from a small undergraduate institution, the WAM program was my first real introduction to the world of math research. Even more important, however, were the connections I made with the other participants and mentors. I can remember one of the organizers told us on the last day that she expected all of us to get our PhD. Hearing someone so confident in my ability was empowering. I keep in touch with many of the people I met at the program, including the woman who became my academic advisor. —2012 participant

I attended the Women and Mathematics Program at IAS at the end of my last year of graduate studies in 1998 … Besides great mathematics, what I remember most was

meeting, for the first time, so many female mid-career researchers in my field. I'd developed the impression that the women all disappeared after graduation, so this was a perfectly-timed boost as I contemplated my own academic career. —Current Professor

I've developed a pile of course materials, inspired and supported by my time at WAM. And that enthusiasm and newly developed "expertise" really helped me win over the computer science students in my cryptology class. These students really don't tend to enjoy mathematics and don't have a lot of respect for mathematicians—but oh, wow, did the students really show a lot of interest and appreciation for the mathematics behind the modern cryptosystems that we discussed. This was a big difference over the last time I taught the course. —Senior Participant at the Cryptography program

The mathematics

WAM has always invited women at the very top of their fields to deliver the weeklong lecture series and colloquia, and has been surprisingly successful in persuading them to come. Karen Uhlenbeck's presence and the fact that it takes place at IAS undoubtedly plays a role. All the participants in the 2018 program appreciated the fact that Toni Bluher managed to persuade her bosses at NSA to let her bring a real Enigma machine to examine. Not so tangible, but equally impressive, was the contribution of Claire Voisin, for example, who lectured in 2015 on her most recent work on birational geometry in an amazingly accessible way.

The theme for each year's program is usually chosen to be closely related to the topic of that year's special program at IAS. However, WAM also aims to cover a very wide range of topics in order to give as many women as possible a chance to participate in the program. Encouraged by the recent presence of Linda Ness on the organizational committee, WAM has also been branching out into some more applied areas. For example, the 2018 program focused on the Mathematics of Cryptography, and the 2022 program will focus on the Mathematics of Machine Learning. The members of the organizational committee play an important role in guiding the selection of topics and lecturers, while the academic manager Margaret Readdy liaises with the lecturers and TAs, explaining how the program works and what is needed from them to ensure its success. Sometimes programs are particularly well-timed, as in the following case.

In 2005, we taught the advanced mini-courses for the IAS Women in Mathematics Program on the Geometry of Groups. Geometric group theory was a relatively new area at the time and was attracting many young people. In retrospect, the program had an amazing impact on the field. The community of young women created at the IAS program has remained a strong and cohesive network to this day and several of the women we first encountered there have become leaders in the field. Moreover, the innovative structure of the workshop, with problem sessions and mentoring events, has influenced the way we, and many others, have designed subsequent workshops aimed at young people. As a result, the field has maintained a welcoming atmosphere for young people, both male and female, and continues to attract a strong and diverse cohort.
—Ruth Charney and Karen Vogtmann

Participants often form lasting relationships that are reinforced when they meet each other later at conferences. This can be especially valuable for graduate students. One attendee reported how lucky she was that the program came just at the beginning of her work on her thesis. When she started going to meetings a few years later, she discovered that she knew people there from WAM. This helped her instantly feel at home and welcomed in her math community. For others, the program may simply (but powerfully) provide a place where they find their mathematical voice:

> *The WAM program has shown me that algebraic geometry can be very enjoyable when lecturers explain the material in a user-friendly way. For the first time, I found myself not only asking people math questions, but also answering.* —2015 participant

> *The second part of my thesis is based on an idea that I first had the courage to say out loud to Nathalie during the WAM. My engagement with this project was fueled by her interest at that time.* —2016 participant

The program also includes one or two colloquium talks, and short research seminars given by advanced graduate students (two to three years to PhD) and postdocs. The colloquium talks often give a wonderful new perspective on the topic at hand, while the research seminars allow each graduate and postdoc speaker to present her work to experts and receive feedback. These opportunities can create useful professional connections.

Other program elements

The program also includes a great variety of workshops and panel discussions, including how to apply to and survive graduate school, applying for NSF grant support, and a discussion of careers with panelists from a wide variety of different mathematical occupations. We also have discussions about family/life issues, the two-body problem, having children—and these are not all theoretical; sometimes lecturers and participants bring their children, which is now facilitated by the Institute's new Child Care program (see below). Often a colloquium speaker eats dinner with the participants and then answers informal questions about her life and career. A great deal of informal discussion and mentoring takes place during the lunches and dinners.

> *When I was a Member at the Institute in 2010–11 I was invited to attend an evening dinner for WAM. I sat down at one of the long tables and was surrounded by about fifteen young women. I asked them to introduce themselves. They were very happy and excited about being able to chat about themselves, their interests, and ask me questions about my life as a mathematician. I realized pretty quickly how much attention each one of the participants craved and that this sort of program was needed.*
> —Margaret Readdy

> *One year … I gave a seminar about "How to say it" for female mathematicians. This was a talk designed to give suggestions to participants on how to use language that would facilitate their experiences interacting with male colleagues. I had done some self-training on this topic while I was an assistant professor and I wanted to pass on this advice to participants. The feedback was excellent, and I felt that I was able to*

communicate something really valuable. I also enjoyed follow-up discussions with students and faculty after this event. —Lisa Carbone

New developments

Christine Taylor joined the WAM program committee in 2012 and over the next five years organized a wide variety of events; for example, a live showing of Gioia De Cari's play *Truth Values*, a public lecture (organized by IAS) given by Tadashi Tokieda, tours by WAM participants of the Princeton Plasma Physics Lab and of the NYC museum MOMATH, WAM participation in a local 5K run accompanied with a math outreach table, and a visit to a Trenton after-school program with a plethora of intriguing math activities. She also worked very hard to update our alumni list and, in 2016, started compiling the yearbooks. They appear on the WAM website at IAS (www.ias.edu/math/wam) and form a wonderful and informative record of what happens each year. These efforts help sustain WAM's commitment to forge a lasting community among the WAM alumni. Most of the lectures are now videotaped, which makes the mathematics more widely available.

IAS Director Robbert Dijkgraaf was very interested in helping to support such activities because they align with his vision of connecting the IAS to both the local and global communities. His office also helped arrange a connection with Johnson & Johnson. Two senior female executives who were originally trained in math gave a presentation one year, and now there is an internship program at J&J for WAM students and alumnae.

When it became time to reapply for NSF funding, it seemed prudent to redesign the program. It now lasts seven days, running from Saturday to Sunday, instead of the previous, more leisurely, ten days. This means that there are now two lecture courses instead of four and there is no longer a two-day weekend break. However, the key elements remain—in particular, time for students to work on problems together, rather than just listen to talks. Organizers also highlight the possibilities for prolonging the connections made at WAM by joining one of the AWM-sponsored Women in … networks or by taking part in one of the many summer research opportunities for small groups that are now sponsored by several of the Mathematics Institutes. The Ambassador program, described below, is another way to take advantage of the connection with WAM.

Other new features of WAM

Computer workshop A new component of Princeton Day is a two-hour computer workshop designed to introduce WAM students to software that is relevant to the subject of that year's WAM program. The difficulty of designing such a workshop varies depending on the field: sometimes it works really well and sometimes not so well, depending on how well-integrated computations are with a particular area of mathematics. However, students planning a career in mathematics need to gain familiarity with the use of programs such as Sage, Maple, or Mathematica, so this effort seems worthwhile. Feedback shows that students appreciate the focus.

Outreach In the past few years, WAM had small-scale outreach in a local school as part of their after-school and Science Day enrichment activities. Beginning in 2019, WAM organized a successful Math Carnival at the Princeton Public Library. The ease with which

low-income and underrepresented students can participate in an event that is walking distance from their homes, coupled with many activities that capture the interest of a wide variety of local K–12 students, resulted in WAM attracting over 120 students on a Sunday afternoon. This is not only an opportunity for the participating children and teens, but also very instructive and enjoyable for the WAM participants who volunteer to run the activities tables with a minimal amount of instruction. We also aim to give WAM participants the inspiration and tools to try similar initiatives at their home institutions, which feeds into the WAM Ambassador Program.

WAM Ambassadors A key new feature of WAM is the Ambassador program, which was designed by Dusa McDuff and Christine Taylor and is supported financially by Lisa Simonyi. As the following reflection shows, WAM participants can have a powerful impact when they return to their home institutions.

> *Yes, I told everyone how amazing it is and hopefully more students at my institution will participate and be inspired. I once mentored a younger student and sent her to a women in math [WAM] conference and she went from having no aspirations to completing the Honors program with goals to pursue graduate school. These events have major impacts.* —Recent Participant

WAM was looking for ways to formalize and extend this effect. Christine Taylor had learned from graduate students in large state universities about the lack of funding even for basic stationery supplies. Thus WAM realized that funding for women- and math-related initiatives at places with limited resources would be truly appreciated and impactful.

The Ambassador program allows WAM alumni to apply for small grants to organize local or regional outreach, whether it be a reading course, tutoring, a community event or regional conference, in order to bring the ideas and energy of WAM to other parts of the country.

> *Being a WAM ambassador was something I'm very proud of since it allowed me to create spaces for female undergraduate and graduate students to connect and empower each other.* —WAM Ambassador

The previous year's ambassadors receive travel funding to return to the WAM program to report on their activities. This also contributes to the cohesiveness of the program from year to year.

Child Care program This new development evolved slowly, from practical necessity. Christine Taylor reported that in 2014, one of the colloquium speakers, Nalini Anantharaman, could only come if there was child care for her daughter. Luckily she had been to IAS before, so the IAS nursery, Crossroads, agreed to take her daughter for a week because they knew her. However, this was not a general solution to the problem.

Lillian Pierce and Christine Taylor contacted the Simons Foundation in summer 2014 to explore the possibility of a child care related travel grant for women mathematicians with young children, but they were uninterested. The next case occurred in 2016, when one of the undergraduate participants would have difficulty attending the program without some financial subsidy to care for her ten-year-old. Christine Taylor talked to Robbert Dijkgraaf, and Dijkgraaf was immediately on board with providing a child care subsidy

for WAM participants. The 2014 proposal was revived, revised, and successfully submitted to the IAS Human Resources office, thus securing child care funding for future WAM participants.

Even more striking, the child care program is now in place for all programs at IAS. WAM and IAS program initiatives have also influenced other research institutes to follow suit. For example, MSRI now has private funds in place to support child care for its members, as well as a summer research program for women mathematicians similar to the Summer Collaborators program initiated by the IAS School of Mathematics.

Funding: a public/private partnership

The funding of WAM has been both a public and private partnership. On the public side, the National Science Foundation has provided funding for the WAM program through its Infrastructure and Workforce in the Mathematical Sciences Programs. On the private side, there are IAS and Princeton University, as well as Lisa Simonyi and past private foundations. The IAS has provided substantial private funding. The IAS does not simply give WAM money. Instead, the IAS raises funds specifically for the program through private donors. So unlike core research in pure mathematics, there are sources of money for programs for women.

> *The past years have been harder with respect to funding for a good reason. There are many other programs for women, and schools and departments have their own ways of encouraging women, so WAM has a lot of competition. This is a good reason to have to struggle!* —Karen Uhlenbeck

Conclusion

This brief description should give some idea of the various elements that make up the WAM program. Bringing them all together requires a great deal of work and patient organization, as well as enthusiasm and new ideas both for the mathematical program and the associated workshops/evening events. The strong support from IAS coupled with the enthusiasm and knowledge of the members of the WAM organizing committee continue to provide inspiration for the WAM program.

> *The climate for women in mathematics and other sciences has improved, but there are still barriers preventing talented individuals from achieving their life goals. The WAM program has enabled me to take my love of mathematics to the national level and encourage women at critical life stages to soar over these barriers.* —Margaret Readdy

> *In the years since its establishment, WAM has been copied but to the best of my knowledge never really equaled, and it is one of the initiatives I was involved with as IAS director of which I am most proud.* —Phillip Griffiths, former IAS Director

Lillian Pierce's insights capture the far-reaching influence of the WAM program:

> *Of course the WAM programs are excellent and beneficial because of the technical expertise they develop in participants. But I think there is something else about the WAM program that is precious and irreplaceable: it allows women in math to find out what*

it means to be relaxed in a mathematical atmosphere. To breathe fully and freely, and to think "ah, this is how it can be, to do math among people who naturally assume I am good at this." The fact that WAM takes place at the IAS is also part of this message: this is an investment in new generations of mathematicians, and a welcoming, a boost, to say "we think you can be great." —Lillian Pierce

Michelle Huguenin has over twenty years of professional experience in higher education, and is the Program Manager for the IAS School of Mathematics.

Dusa McDuff was born in London to an academic family with a long tradition of activism. Now at Barnard College after many years at Stony Brook University, she is a Fellow of the Royal Society, a member of the National Academy of Sciences, and was awarded the Sylvester medal in 2018.

Margaret Readdy works in algebraic combinatorics. She is the first person in her maternal family to go to college, the first PhD in her family, and the first woman to be promoted to Full Professor of Mathematics at the University of Kentucky.

Karen Uhlenbeck is Professor Emerita at the University of Texas in Austin and Distinguished Visiting Professor at the Institute for Advanced Study, Princeton. She is the recipient of many awards including a MacArthur Fellowship, the National Medal of Science, and the 2019 Abel Prize.

16

The Infinite Possibilities Conference

Creating Moments of Belonging

Lily S. Khadjavi, Tanya Moore, and Kimberly Weems

Sometimes remarkable creations come from a moment of gratitude. In 2003, on an uncharacteristically misty afternoon in Los Angeles, Spelman alumnae found themselves serving as members of the audience for a dozen middle-school-aged girls. All shades of brown skin reflected beautifully against the white lab coats the students proudly wore, as they explained their science experiments with big smiles. Ostensibly, the Spelman graduates were to serve as role models for the girls. They fulfilled their designated role … and much more. The experience inspired them to reflect on their time at Spelman as mathematics majors, the uniqueness of their college experience, and the critical role of professors who served as role models that balanced high expectations for academic performance with support and encouragement. Although they did not realize it at the time, those Spelman faculty offered them their first glimpse of a mathematical community.

The two alumnae continued to talk with each other about their college peers with whom they had worked collaboratively on problem sets and exam preparation. They remarked on how many of the Spelman math majors had gone on to graduate school, successfully completing master's and doctoral programs in mathematics, statistics, and related fields. The conversation then segued to the recent passing of Dr. Etta Falconer, a Spelman giant who was instrumental in increasing opportunities that supported Black women mathematicians and scientists. In appreciation of the Spelman experience that launched so many women into math careers, they thought out loud about how great it would be to have a reunion or celebration to bring everyone back together, to honor Dr. Falconer, and to acknowledge the contributions of the math faculty in shaping their paths. Then Marlisa Johnson turned to Tanya Moore and said, "You should do that." At that moment, the Infinite Possibilities Conference (IPC) was born.

The first IPC

IPC was created with the mission to support, encourage, and celebrate underrepresented minority (URM) women[1] in the mathematical sciences. The first IPC was organized under the leadership of Leona Harris, Tanya Moore, and Nagambal Shah and took place at Spelman College in 2005. In grassroots fashion, they assembled an organizing committee of URM women mathematicians who, along with faculty and staff of Spelman College, thought that IPC could form part of a response to the problem of underrepresentation.

Even as of 2018, only two percent of doctoral degrees in mathematics were awarded to Black, Latina, and Native American women in the US [3, 6], while those same groups comprise approximately seventeen percent of the US population. Even earlier in the pipeline, fewer than six percent of bachelor's degrees were awarded to URM women in the mathematical sciences [6]. The largest share of bachelor's and doctoral degrees in the mathematical sciences was awarded to white males, 32% and 51% respectively [6]. While the overall number of doctoral degrees in mathematics has increased between 2006 and 2018, the number of URM women receiving those degrees has stayed relatively flat. In tandem, the persistence of stereotypes of the typical mathematician has held strong. In most minds, the image of a mathematician or scientist conjures up a white male, and the data regarding who receives a degree in mathematics at the undergraduate and graduate level support that association.[2] The lack of diversity in the mathematical sciences becomes a self-fulfilling prophecy—a cycle of acceptance around traditional notions of who rightly belongs in the mathematical community.

Armed with personal testimonies and their awareness of the lack of representation of URM women in the broader math community, the organizing committee set out to design the first IPC. The initial planning discussions provided an opportunity to envision a conference they would want to attend. The organizing committee posed exciting and empowering questions: What kind of workshops and speakers should be featured? Should the conference target only Black women, or all women? What were the key elements of environments, programs, and relationships that supported success in completing graduate school? What needs to be known and shared with other women interested in math?

It was ultimately decided that there was a unifying experience of Black, Latina, and Native American women in math, in that their identity stood in direct contrast to the ste-

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[1] Consistent with language adopted by academic institutions, we use the terms "underrepresented" or "minority" (or URM) to refer to someone who self-identifies as Black/African-American, Hispanic/Latino(a), Native American or Alaska Native, Native Hawaiian, or other Pacific Islander. We also use "women of color" to refer to racial or ethnic groups traditionally marginalized in the United States and to those who self-identify with the term woman. The term BIPOC, or Black, Indigenous, People of Color, recognizes the complexity of marginalization. While some scholars have pointed out that terminology can implicitly suggest white as neutral and in effect essentialize racial groups, these more recent umbrella terms are embraced by many activists and have the advantage of moving away from majority/minority designations.

[2] In a striking "Draw a scientist" study which originated in the late 1960s and has been repeated in more recent eras, children drew male images far more often than female. In the study's first iteration, out of over 4800 drawings of scientists, only 28 were of women (all drawn by girls). As of 2008, children still drew twice as many male figures as female, whereas for professions such as teacher, only a quarter of the sketches were of men [9].

reotypical image of a mathematician. So IPC would be created intentionally for them, by them. There was also a desire to create a platform to showcase different career paths chosen by women who love math. IPC could expand awareness beyond the perceived limited professional opportunities available with a math degree as well as combat conventional beliefs of who could do math; hence, the organizers chose the name "Infinite Possibilities."

As the organizers planned a combination of plenaries, panels, and smaller parallel sessions, they wanted to address and share the multi-faceted factors contributing to retention in the field, such as the importance of being seen and valued, feeling connected, and finding the appropriate level of challenge to excel. As the only (or one of a few) URM women in their graduate program, many of the organizers had begun to question whether they belonged in mathematics and if they could be part of the broader math community without sacrificing their identity. If the conference could provide an opportunity for URM women to know that they were not alone and that relatable models of success existed, then perhaps it could provide encouragement for those in attendance to persist.

Many of the Spelman graduates on the organizing committee had experienced the privilege of mentorship from Spelman faculty that extended into their time at graduate school. Was there something different about mentoring women of color in mathematics that should be explored? The organizing committee also aimed to have all aspects of the pipeline represented, from students to professionals in the field, in order to provide opportunities to connect to role models and encourage networking. These are activities that have been identified as effective mentoring strategies, especially for women of color in the mathematical sciences [5]. The first conference would include a panel discussion on mentoring women in mathematics and a session that proactively facilitated dialogues on mentoring among women at different stages in their journey. Linking high school students to undergraduates to graduate students to professionals could provide connection points to "near peers," with the belief that near peers can often provide the most useful advice and insight for the next step in the journey. Moreover, the intent was for the conference to create a community of mentors of various roles, such as advocates, role models, peer

Photo credit: David Weisbart.

IPC Group Photo at UCLA, 2010.

mentors, and coaches, who could augment existing mentoring structures at their home institution or industry [2].

Acknowledging that the gold standard for success in academia is often publications, the organizers felt compelled to support one another along the research path by providing a supportive environment for sharing, receiving feedback, and dialoguing about research, necessary steps in the process of becoming a high-caliber mathematician and researcher. It was important to include opportunities for IPC attendees to communicate their results during the conference through Research Roundtables, concurrent sessions of oral presentations that showcased the participants' work in applied mathematics, mathematical biology, mathematics education, pure mathematics, and statistics. Students could also make poster presentations. These sessions would provide a supportive environment to discuss and receive feedback on theses, dissertations, works-in-progress, and research reports.

The participation of Spelman alumnae and faculty in the planning of the first IPC influenced another key decision. To honor the legacy of Etta Falconer, the IPC Steering Committee, Spelman College Mathematics Department, and the Falconer family established the Dr. Etta Z. Falconer Award for Mentoring and Commitment to Diversity. The award recognizes the importance and value of individuals who make significant efforts toward building connections and community. For her dedication to increasing the number of women and Black students in mathematics, Janis Oldham of North Carolina A&T State University became the first Falconer recipient. As noted by her nominators, Oldham embodies the spirit of Falconer by having high expectations of her students and a willingness to invest generous amounts of her time to nurture their mathematical development.

Initially, the organizers planned to have just one conference. But after the closing banquet of IPC 2005—which opened with a drum ceremony, gave tribute to Falconer, presented an overview of the history of URM women in mathematics by Sylvia Bozeman, and honored Oldham with the Falconer award—the room was filled with tears and full hearts. Initial feedback on evaluations from the first conference further validated the organizers' intuition about the importance of providing a space for women of color to feel supported and more connected within the math community. As a result, planning for the next conference began.

The power of reflection and critical mass

We can all understand the power of images to influence our beliefs. Many of the organizers for that first IPC were newly minted PhDs and had their own personal experiences in graduate school fresh on their minds. They shared their need to form their own communities outside of mathematics or to seek therapy in order to cope with the stress, doubt, and sense of isolation while in school. For those who attended a Historically Black College or University (HBCU) as undergraduates, their first introduction to a math community had included supportive faculty and peers.

Professors and classmates served as living proof of the possibility to obtain educational degrees and achieve professional success. The question of gender or race as linked with skill in mathematics was implicitly removed from consideration. While this knowledge fortified them, as they pursued graduate-level education in environments that were radically different from HBCUs, the sense of isolation and the experience of not fitting in could still be painful and challenging to navigate.

The numerical data for URM women in math imply that most are the only (or one of very few) women or URMs at their respective institutions. One of the most common themes from conference evaluations by attendees focused on how IPC made them feel less isolated by being in the presence of so many women with whom they identified. Attending the conference encouraged them to continue along their paths in mathematics.

> *Mostly it made me feel less alone, which has made me a little more comfortable pursuing the PhD.* —IPC attendee

> *The conference is one of the most encouraging conferences I have been to. I found inspiration and made connections with women who 'looked' like me or had the same 'walk.' I am more determined to finish my PhD and to continue to build my village. I sincerely will recommend this conference to all mathematicians and scientists (females). Let me know how I can be more involved.* —IPC attendee

Impostor syndrome is a common experience among many students and professionals in the academic environment, regardless of background or identity. This feeling challenges one's belief that success in math is possible. The suspicion that one has been let in "by mistake" is further exacerbated by the experience of not fitting in. Additionally, when faced with microaggressions or more explicit comments regarding doubt in ability, impostor syndrome begins to feel like a credible belief. IPC provided a brief but impactful respite from the questions and doubts of belonging by bringing in URM women *en masse*. When we think about the fact that there are on average twenty URM women that complete doctorates in math each year in the US, being in a room with 100–200 URM women all at one time takes on another level of significance (Table 16.1). With this moment, there is an opportunity for seeing to translate into believing that belonging in math is possible as a URM woman.

> *While attending IPC I was very doubtful if I should continue striving toward a PhD because I had one more qualifying exam to pass that I had taken four times already. But after attending IPC and talking to many of the very inspiring women who were just like me, it made me see that I am not alone, and if they could do it, I could too. So that June I took the test, passed it and even received a fellowship for the next year. I am extremely grateful to have been a part of IPC; it is a conference that was both inspirational and educational to me. It is an experience I will never forget.* —IPC attendee

> *My first conference was a pivotal moment in helping me see my personal fear in pursuing a doctorate degree (feeling like "I can't do it") and address this fear along with seeing my true desire to earn a degree and follow my passion.* —IPC attendee

> *It made me believe that I can be one of the professors in a future meeting.* —IPC attendee

Wherever possible, IPC sought to put notable URM women in math at the forefront of the conference. Critically, the organizers themselves reflected the intended audience, and the conference showcased the accomplishments of women of color who were featured as plenary speakers and panelists. Photographs of attendees were included throughout the conference proceedings. The reflection of URM women in every aspect of the conference was very purposeful and important.

	2005[3]	2007	2010	2012	2015	2018
Total Registrants	148	206	191	288	203	135[4]
% Female	95%	94%	96%	90%	86%	96%
% URM[5]	87%	70%	81%	70%	53%	78%
% URM Women	85%	67%	79%	67%	49%	76%

Table 16.1. *IPC registrant totals and demographics between 2005 and 2018.*

For some of the organizers, the relationships with former undergraduate professors continued throughout graduate school, helping them to contend with a sense of isolation and a new environment. The conference became a vehicle to express appreciation for the dedication of these mentors. Mentors can have an especially significant role in supporting long-term success for women of color in STEM fields pursuing graduate degrees [7]. Yet, the work of mentoring is often not as visibly acknowledged as other aspects of professional activities. To honor this important work, the culminating event of each IPC has been the presentation of the Dr. Etta Z. Falconer Award for Mentoring and Commitment to Diversity, recognizing individuals that were nominated by their mentees and colleagues and selected by a panel of reviewers. Past recipients of the Dr. Etta Z. Falconer Award include Janis Oldham, Sylvia Bozeman, Ivelisse Rubio, Roselyn Williams, Genevieve Madeline Knight, and Javier Rojo.

Addressing intersections of identity

> *Your conference fulfills a unique role in the mathematical community. You inspire and encourage young and minority women to excel in mathematics and address the concerns of being a professional and leading a satisfying life. Your holistic approach has produced two exciting conferences that are to my knowledge completely new to the math world.* —IPC attendee

From the outset, the Infinite Possibilities Conference was implicitly designed to address the intersections of identity. Noted legal scholar Kimberlé Crenshaw introduced the idea of intersectionality in the late 1980s as a legal theory in order to shine a light on the inadequacy of the law in addressing racism and sexism, and indeed other forms of discrimination, when it failed to take into account the "intersection" of individuals' identities. The notion of intersection is of course fundamental to mathematicians. An intersectional perspective in this context requires us, as a mathematical community, to take into account how, for example, a woman of color might experience gender bias differently from a white woman. People at the intersections can even inadvertently be displaced, and there is a need to address their experiences. While valuable mathematical programming has been created to support women or to gather students and researchers of color, few initiatives are aimed specifically at those in the intersections. (To put another mathematical spin on it,

[3] Estimate based on partial demographic data.

[4] Attendance intentionally capped because of space constraints at host institution.

[5] URM includes Black/African American, Hispanic/Latino, Native American, Pacific Islander/Native Hawaiian, and Bi- or Multi-Racial.

the many labels for race/ethnicity, gender, sexual orientation, marital status, religion, and so on, are not mutually exclusive.) How, then, can we create a mathematical community where we don't have to check some part of our identity at the door in order to enter?

> *I was able to connect with other women of color who are in [the] mathematics field and learn how they navigated the academi[c] world.* —IPC attendee

While mathematics has been a consistent theme at each IPC with parallel research talks and poster sessions, over the years the programming committee has always made space for participants to directly discuss the intersections of their identities and their academic experiences. Sometimes these conversations have taken place in plenary panels and sometimes through small-group discussions. All spaces created a comfortable venue to share experiences and advice.

Sessions on race and gender issues elicited stories that illustrated the common experiences of isolation, tokenism, and more. Even seemingly incidental examples reported in the very first Proceedings of IPC, paraphrased here, captured these sentiments: One student expressed frustration at feeling like a token as an undergraduate when a faculty member said to her, "Do you know how good it would make us feel to have a Black female go to graduate school?" Discouragement could come from fellow students, as in, "Many had teaching assignments and when a student heard I [a Latina female] had a fellowship [that year], he said, 'Oh, if I changed my name and gender, I'd have one too.'"

These encounters had not created a sense of belonging in the programs where they occurred. Importantly, IPC was an opportunity to express these frustrations and larger challenges, at every level of participants' careers, in a safe space. Attendees shared suggestions for building support.

Later IPC programs have included sessions on the many intersections of our lives: sessions on balancing career and personal life, challenges of motherhood, being LGBTQ in mathematics, and more. Parallel sessions allowed us to create smaller group discussions

Photo Credit: Frederick Moore.

(From left) Kimberly Weems, Tasha Inniss, Evelyn Boyd Granville, Lee Lorch, and Sherry Scott. IPC at Spelman College, 2005.

that also spoke to participants at their specific stage in education and career. While college students could attend a session on applying to and thriving in graduate school, those later in their studies or career could discuss negotiation skills and fighting gender and racial stereotypes in the workplace. Specifically targeting the retention and advancement of faculty, Kerry Ann Rockquemore, founder of the National Center for Faculty Development and Diversity, led a workshop on "Solo Success: How to Thrive in the Academy When You're the Only _____ in the Department."

> *I have multiple identities: by race/ethnicity, gender, as a math nerd, by my [sexual] orientation … IPC has been a space where I can find community. I feel a sense of belonging in the mathematics world here, with others who don't need to match me in every characteristic.* —IPC attendee

Living history and Hidden Figures

> *It really gave me more push and motivation to finish my degree. I was surrounded by women who were great mentors and inspiration for me.* —IPC attendee

> *I got to see influential women in the mathematical sciences who looked like me but also who had gone through struggles and overcome similar obstacles like myself in order to pursue education.* —IPC attendee

The first IPC featured a special keynote speaker, Evelyn Boyd Granville, one of the first Black women to earn a PhD in mathematics. Granville's very presence gave conference attendees a powerful connection with their history. Her rendition of the debate regarding

Photo Credit: Edray Herber Goins.

(From left) Tanya Moore, Margot Lee Shetterly, Christine Darden, and Ulrica Wilson. The Mathematics and Mathematicians behind Hidden Figures *Panel, Joint Math Meetings, Atlanta, Georgia, 2017.*

the first Black woman—Euphemia Lofton Haynes, Marjorie Lee Browne, or Granville—to receive a PhD in mathematics served as a priceless testimony celebrating this groundbreaking achievement as a whole rather than as an individual accomplishment [1]. Even more, Granville's mentor Lee Lorch, himself a civil rights activist and mathematician, also attended the event. To round out the weight of the moment, after Granville spoke, she posed for a picture with Tasha Inniss, Sherry Scott and Kimberly Weems, the first Black women to receive doctorates in math from the University of Maryland. Subsequent IPCs have featured trailblazers including Freda Porter, an entrepreneur and one of the few Native American women with a PhD in mathematics, and Ruth Gonzalez, recognized as the first US-born Mexican-American woman to earn a PhD in mathematics [4].

So often, when history is discussed in mathematics courses, the names mentioned are connected to the theorems and equations that fill textbooks. We know the names of Euler, Descartes, and Pythagoras, but we are less familiar with the names of Granville, Gonzalez, or Porter. These pioneers and role models are important to inspire future generations of URM women. Not only have they paved a way forward, but they also serve as examples that it is possible to complete advanced studies in mathematics. Plenary speakers discussed a range of mathematical subjects, often sharing their personal journey in mathematics—both highs and lows. The IPC provided an opportunity to demonstrate that URM women have made and are making meaningful contributions to the field of mathematics.

Upon learning about the upcoming release of *Hidden Figures*, the book and movie that showcase Black women's contributions to mathematics, computing, and space exploration, IPC co-founder Tanya Moore conceived the idea of creating some type of IPC and *Hidden Figures* collaboration. The connection was evident, with IPC striving to promote URM women in mathematics and *Hidden Figures* shining a spotlight on unsung "shero" mathematicians behind aeronautical breakthroughs. The timing could not have been more perfect as the film's screen release date was in late December 2016—just weeks prior to the largest gathering of mathematicians in the country.

Thus, at the January 2017 Joint Mathematics Meetings in Atlanta, IPC—along with its umbrella organization, Building Diversity in Science—partnered with the American Mathematical Society, Association for Women in Mathematics, Enhancing Diversity in Graduate Education, and the National Association of Mathematicians, to sponsor a panel on "The Mathematics and Mathematicians behind *Hidden Figures*." Moderated by Moore, the panel featured Margot Lee Shetterly, author of the book on which the movie is based; Christine Darden, retired NASA "human computer" whose contributions are discussed in the book; and Ulrica Wilson, Associate Professor of Mathematics at Morehouse College, who presented the work of another hidden figure, Dorothy Hoover.

This panel broke down walls—literally and figuratively. Originally, the event was assigned to a room with space for about 200; at the last minute, staff removed room dividers to increase the capacity and accommodate the massive crowd. This panel marked the first time IPC programming was introduced to the broader, mainstream, (inter)national mathematics community. To the delight of the organizers, positive response to this panel was overwhelming, and it is their hope that after hearing about the struggles and accomplishments of hidden figures, attendees who may have felt like outsiders began to experience a sense of belonging in mathematics.

The power of learning this history is captured in inspiring terms by Shetterly in the prologue to her book: "What I wanted was for them to have the grand, sweeping narrative that they deserved, the kind of American history that belongs to the Wright Brothers and the astronauts, to Alexander Hamilton and Martin Luther King Jr. Not told as a separate history, but as a part of the story we all know. Not at the margins, but at the very center, the protagonists of the drama. And not just because they are black, or because they are women, but because they are part of the American epic [8]."

Looking towards the future

Each IPC has been planned by a group of women from around the country who volunteered their time to make IPC a reality. Membership in the organizing committee intentionally changed for each conference in order to continue to bring fresh ideas and diverse perspectives to the program. Meanwhile, at each host institution, a local committee supported the conference activities. A consistent group of women provided leadership from year to year as members of an IPC Advisory Board. Members of the IPC Advisory Board have included Erika Camacho, Leona Harris, Lily Khadjavi, Tanya Moore, Nagambal Shah, and Kimberly Weems, who shared their perspectives on sites for the conference, key themes to incorporate, and suggestions for organizing committee members.

Though the first IPC was a grassroots effort, the leadership realized the need to form collaborations for sustainability of the initiative. After the first conference, IPC formally joined a non-profit, *Building Diversity in Science*, whose mission to inspire, empower, and support underrepresented groups in the pursuit of STEM careers aligned with the goals of IPC. Early in the history came a partnership with the NSF Math Institutes. These collaborations resulted in increased staff support for essential tasks such as registration, travel reimbursements, and advertising, and allowed the organizing committee to focus more of its energy on creative programming for the conference. Primary and consistent conference support was obtained from the National Science Foundation and, in various years, the National Security Agency, host institutions, and other corporate funders. A significant portion of the funding went towards providing student travel scholarships and for underwriting the majority of conference expenses in order to keep registration fees low. Partnerships have been critical to IPC's ability to endure over the last fifteen years.

> *The conference really lifted my spirits and helped me to move forward. As a first year graduate student, I needed to hear the stories of women who look just like me who have also struggled with racism, sexism, and favoritism in their respective institutions but through faith, help, and support from family and peers, and, most importantly, with strong determination were able to overcome these obstacles and succeed. After the conference I came back to my school rejuvenated and ready to take on the world.*
>
> —IPC attendee

As the only program of its kind, IPC has aimed, since 2005, to sustain the spark for women who have an interest in math. IPC creates a space where personal identity doesn't have to be separated from identity as a mathematician. Shared cultural experiences help establish a community in mathematics so that participants are not alone in their academic and professional pursuits. We have learned that a two-to-three-day conference, as one

piece of a web/network of activities, can make a difference. The founders set out to create a conference to honor their *alma mater* and share the best of what they received with other women like them. They wanted a conference that created community, embraced the full identity of participants, and highlighted relatable models of success for students and professionals. They came to see it as creating belonging.

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17

On Building a Research Community of Women Mathematicians in Africa

Karin-Therese Howell and Nancy Ann Neudauer

A call

What do we do when a mathematician tells us she cannot collaborate with a male mathematician—her husband won't allow it? And he won't let her travel to conferences without him, but his work keeps him from being able to accompany her? It's part of her culture, she explains. What do we do when student after student, even graduate students, tell us that they have never seen a woman lecturer and claim that there are none in their country? What do we do when there are no women at the highest ranks in academia in countries that do have women mathematicians? How do we support women in mathematics? Can we smooth out this journey and make sure that more advance? Can we shake things up a bit?

We need to increase the *visibility* of women mathematicians in Africa. We need to increase the *opportunities* for women mathematicians in Africa.

We want to create a space where women can work together, present research in a supportive environment, get ideas for extending their research, collaborate on new problems, and discuss challenges faced by women in mathematics, and women in Africa. We want to welcome them just as our teachers and others have welcomed us, just as so many mathematicians have let us know that we belong.

A first step: creating a research conference

As a way to begin, we each organized a research conference for women mathematicians from many countries in Africa. Talks by women on their research form the backbone of these conferences, often beginning with some introduction for the non-expert. Ample time to work together on open problems and for starting joint projects complement the talks. Panel discussions of interest to both students and working mathematicians sup-

plemented the research talks at the first two conferences. Topics included creating an environment that includes women mathematicians, finding grants and other sources of funding, balancing work and family, and experiencing and dealing with inequities.

Our main goals are to *build a research community* of African women mathematicians and to *increase the visibility* of women in mathematics among African students, researchers, lecturers, and professors. We hope that this community will impart support to participants at all stages in their careers and continue to serve as a network they can turn to as they advance through the profession. The conferences provide a safe space to discuss mathematics.

We are just getting started. Building a community of women mathematicians in Africa is a recent endeavor of ours; let us tell you how we began.

Nancy's story

"There aren't enough women lecturing here," Robert Beezer of the University of Puget Sound said to me in early 2013, while he was teaching a course at the African Institute for Mathematical Sciences (AIMS) in South Africa. He proposed that we team-teach a course there the following year, and he laid out an ambitious plan whereby I would apply for the Fulbright Specialist Roster, teach a course with him, and then return the year after that to AIMS Centres in other countries. He would propose our course to the Academic Director right away, if I was willing. And that's how I got to Africa.

AIMS delivers an intensive, year-long structured master's program to students from across Africa. At least 30% of the students are women, a much higher percentage than is typical among graduate programs in Africa. In 2008, the Next Einstein Initiative was founded to create AIMS Centres in other African countries, and so far this same program has been replicated in Ghana, Senegal, Cameroon, Tanzania, and Rwanda. Many of the AIMS Centres also have a Research Centre with postdocs, students, researchers, and visiting researchers from around the world.

A rapid journey from never-thinking-of-travel-to-Africa to fourteen trips in six years (including AIMS institutes in South Africa, Tanzania, Ghana, Cameroon, and Rwanda) followed from Rob's suggestion.

It is a privilege to be invited to AIMS—visiting lecturers include Fields medalists and Nobel laureates. With these trips, I am honored that my involvement with AIMS in several countries allows me to contribute to the growth of mathematics in different countries and build ties with African mathematicians. This has been one of the most rewarding professional experiences of my career. Connections formed in this network have led to research collaborations and to visits to my own university by lecturers I have met at AIMS Centres.

While at the AIMS Centres, I have noticed what Rob pointed out—that there are not many women amongst the faculty; I have also observed this lack of women at universities I have visited in these African countries. In some ways it reminded me of my own experiences both as a graduate student and faculty member. I had benefitted from my involvement in communities. The community in the AIMS Centres was already helping many young mathematicians. I still wondered, however, if something more could be done, specifically for female mathematicians.

As I met women in my own area of discrete mathematics—a master's student from

Nigeria, a computer scientist from Cameroon, a PhD student from Namibia—it became clear that the travel distances would be long. I had visited mathematics institutions in five African countries and had an idea that some of the women I met were quite isolated, that there simply was not a high enough concentration for a community in some places. It occurred to me that if I introduced them to each other, a network would emerge. I looked for a place where a concentration of women mathematicians already existed—a place where more frequent meetings might be possible, or a good place to host a larger conference.

A first conference

While I was thinking of what I might do in Africa, a contact from graduate school (a strong community of its own, it turns out) sent me a Call for Proposals from the International Mathematics Union Committee for Women in Mathematics (IMU-CWM) looking to fund conferences and activities in developing countries at the continental level. In reading the description, I realized that this is how I could give something back—by organizing a conference that would bring together some of the women in mathematics I had met all over Africa with the aim of building a robust core of people who could start their own network. This was the genesis for the Workshop for African Women in Discrete Mathematics and its Applications at AIMS-South Africa in January 2018.

This particular venue was a natural choice for several reasons. I had a connection with AIMS and could align teaching a course there with the conference, giving the AIMS students a conference experience and offering them more exposure to women mathematicians from throughout Africa and the world. At any time, AIMS-South Africa has a dynamic population of around eighty master's students and tutors from across Africa. It has its own Research Centre and is close to several universities, providing a rich body

Photo Credit: AIMS South Africa.

Workshop for African Women in Discrete Mathematics and its Applications, January 2018.

of potential speakers and participants. It is also near a major airport making travel to the conference easier, and has other resources that make such a meeting feasible. AIMS was willing to give us the space for lectures and smaller meeting rooms, host an opening reception, provide food on site, and even offer some accommodation. Through AIMS and its vast network I was able to identify women mathematicians and also women graduate students to invite to the conference.

The IMU-CWM grant that sparked my organization of the conference awarded 1800 euros. Although this was not a lot of money, it was enough to support the attendance of several local students and also bring some of the discrete mathematicians I had met through AIMS to the conference. The master's student from Nigeria, Sofiat Olaosebikan, who was a student in my 2014 course at AIMS-Ghana and later completed her master's thesis under my supervision, was now a PhD student in Glasgow, and she was able to come with one of her classmates, Frances Cooper. The computer scientist from Cameroon, Nathalie Wandji, who was a tutor for my 2016 class at AIMS-Cameroon, traveled 2000 miles to attend. The grant also allowed me to invite graduate student Martha Kamkuemah from Namibia as a local organizer. Her PhD advisor, AIMS South Africa Academic Director Jeff Sanders, thought it would be a good professional experience for her to help with the conference, and certainly it was a benefit to the conference overall having someone local help with the planning.

All four of these talented women gave fantastic talks at this international conference. The funding also supported the attendance of local students.

My university provided support for two of my undergraduate students to attend the conference and present their senior research. Their talks not only introduced most conference participants to undergraduate research but they also surprised them with its possibilities. My students had a transformative experience as well because 61 mathematicians attended the conference representing 23 countries, eighteen in Africa.

The day before the conference started, the Director of AIMS-South Africa, Barry Green, told me that he hoped this type of workshop would lead to a new collaboration between a mathematician from one of the South African universities and a mathematician from outside Africa. At the opening reception it was already evident that the conference had brought together women who would not otherwise have met. Indeed, in one of the first talks, Karin-Therese Howell, who I was meeting for the first time, asked if anyone knew if her work was related to matroids. Since my research is in matroid theory, I suggested we investigate this idea. I certainly did not foresee a question so directly related to my own research.

The first panel at the workshop was on *Building Mathematical Communities*. Rob Beezer and I gave an overview of work we had done in building communities, including with the discrete mathematics gathering we revived and co-organized for seventeen years in the Pacific Northwest. In addition, Jeff Sanders discussed communities he had helped form at Oxford University and elsewhere. We stressed what it took to keep communities going: a dedicated organizing team and a core group of people with the commitment and discipline to show up to each event.

We ended the workshop with an open conversation on *What's next?* Here we recapped some of our previous discussions and began making plans for future meetings of this type and for building a community starting with those who attended this workshop. I hoped

this would convince at least one of the local mathematicians to take the torch and organize another conference—to be a local force working to build this new community. Which brings us back to Karin-Therese.

Karin-Therese's story

I have always been in South Africa. I was born, raised and secured my first job in Kimberley in the Northern Cape. I trained at the University of the Free State in Bloemfontein and then returned to Kimberley and accepted my first position as a lecturer and, later, manager of student affairs at the National Institute of Higher Education (now the Sol Plaatjie University) while I was completing my master's degree. It is there where my passion for mentoring female students was sparked. I could see that many women had big dreams but their anxiety about mathematics was a stumbling block in completing their studies. In particular, I mentored one student and helped her overcome her mathematics anxiety. She went on to successfully complete her studies, qualify as a journalist, and now has a senior managerial position in the local government. I still remain in contact with her. This interaction imprinted on me how we just sometimes need someone to remind us that we are capable, that we belong, and that we should never give up in the pursuit of our dreams. Since 2009 I have had a position at Stellenbosch University, just outside of Cape Town. When I started I was one of a handful of women in the mathematics division, but since the appointment of Ingrid Rewitzky as the executive head of the Department of Mathematical Sciences, we now have many female mathematicians. I wondered how we could open the path so that more women could rise to leadership positions.

In 2017, at a time when I felt very lost in my own career and dreams, I found a notice of a conference in Australia for women mathematicians. I travelled to attend the first

The plenary speakers from the 2019 AWiM Conference: Nancy Ann Neudauer, Nouzha El Jacoubi, and Ingrid Rewitzky.

Women in Mathematics Special Interest Group of the Australian Mathematical Society (WYMSIG) conference in Adelaide. The conference had a strong research component, but also many interesting presentations and panel discussions, ranging from how to market your research to career planning. There were female mathematicians from all walks of life. I left renewed and inspired, with some wonderful new friends, a new research problem and collaborator, and with a dream to replicate something similar in South Africa. The conference and conversations taught me that every woman's journey in mathematics is unique. When I returned to South Africa I started voicing my dream in our department and everywhere I went. Slowly, like building a puzzle, pieces began to fit, one by one.

A second conference

I met Nancy at the Workshop for African Women in Discrete Mathematics conference in January 2018. I was inspired by the sense of community. Nancy and I began talking about collaborative work and a second conference for women in mathematics. Later that year, our head of department, Ingrid, notified me of a call for funding by the IMU-CWM (the same organization that had helped fund Nancy's conference) for activities related to women in mathematics. Soon after that funding was secured, some more financial assistance from Stellenbosch University followed. A contact through AIMS put me in touch with Nouzha El Jacoubi, the president of the African Mathematical Society, who already had plans to be in South Africa during the time we were planning to host the conference. A few months later, colleagues in my department notified me of some funding they had left and were willing for it to be transferred to our conference. Little by little the pieces came together and in July of 2019 the African Women in Mathematics Conference (AWiM Conference) was held at Stellenbosch University.

Photo Credit: Anton Jordaan, SCPS.

African Women in Mathematics Conference, July 2019.

The aim of the conference was to empower women researchers and assist in the building of a mathematical community in Africa, in collaboration with existing associations in Africa. Nancy was a plenary speaker and offered a seminar in Matroid Theory. For the majority of the women, it was their first exposure to matroid theory. Women mathematicians offered talks in both pure and applied mathematics and there were panel discussions on dealing with inequities in the work environment and balancing work and life. There was a session on how to identify good problems to work on and some problem sessions in specific research areas. There were 52 mathematicians at the conference from eight countries, including Nigeria, Benin, Madagascar, Kenya, Ghana, and Morocco.

Support for the conference came from all over the world. Lesley Ward, the Australian Mathematical Society WYMSIG 2017 conference director, Kerstin Jordaan, then South African Mathematical Society chairperson, Carolina Araujo and Marie-Francoise Roy, the vice-chair and president of the IMU-CWM, respectively, all sent messages of support that were either read or played at the opening ceremony. Ward and Jordaan will come in-person to the next conference. Our community was already bigger than just the conference; there is a worldwide movement, and we are part of it.

We hope subsequent conferences of this nature will assist in establishing a network of researchers, thereby encouraging new collaborative projects and the mentoring of the next generation of African female mathematicians. Women are still very underrepresented in the mathematical sciences, even more so in Africa, and by increasing the visibility of women mathematicians, we hope that girls will have role models and consider pursuing mathematical sciences at the tertiary level.

Looking back

The two conferences consisted of research talks by women at all stages of their careers and a wide array of professional experiences; the first focused on discrete mathematics while the second showcased all areas of mathematics. An introductory seminar on matroid theory was a feature of the second conference, and an accredited version is planned for the third. Some women at their home institutions have to spend an inordinate amount of time on service to the university as a side effect of having few women to populate the committees and as a result have less time to focus on their own mathematics. Thus these conferences provide a critical opportunity to reboot their research. Through informal gatherings for participants to get to know each other and to discuss possible research collaborations, the edges connecting the nodes of a new network began to fall into place.

Panels at the two conferences specifically addressed the situation for women mathematicians. Reflecting on this, it became clear that we have some shared experiences, including some slights that have happened in the workplace or in graduate school. One woman, for example, was in a department where a European colleague recently told her, "Things were easier before there were women in the department." We also have experiences that vary, often depending on where we are from. Participants discussed what they were doing in some cases to push back against ingrained patriarchy and noninclusive cultural mores and norms. Others focused on how to coexist within the structures. One participant had been active in trying to make a change in her home country of Malawi and discussed how she now also worked with men to let them know what they could do to make it possible for women to succeed. There was a discussion of cultural patterns that have made this

difficult, including women being forbidden by their husbands to meet or collaborate with male mathematicians. There was a discussion of women not being allowed to travel without a male companion. These conferences are providing networking and research opportunities both for women who are geographically isolated and for women who, by their culture, are more easily able to attend a conference of women mathematicians. A research collaboration with a woman might be easier to sustain in this context. The conferences also provide a safe space for all women to present and discuss mathematics. Lack of funding to support research and travel to meetings is a hurdle to involving even more women.

At the first conference, after the Opening Reception, we showed the movie *Hidden Figures*. The idea for adding the movie to the program arose from learning that the US State Department shows it throughout the developing world in an attempt to encourage girls and women to pursue studies in STEM fields. In the discussion following the movie, African mathematicians commented on shared experiences among women in the US and in South Africa. This was a powerful experience for participants from many countries.

The visibility of women mathematicians was certainly increased for conference attendees which included men and women. All speakers were women, which was new for everyone there. The conferences have also increased the visibility of women mathematicians beyond the conference, both to the general public and to other mathematicians. In particular, television and newspapers reported on the events of both conferences, as did mathematics newsletters across Africa.

Measuring success

Outcomes of these first conferences include creating a network of African women with common mathematical interests, generating ideas for new research, and extending current research through open problem sessions. As hoped, this is supporting women in mathematics throughout Africa at all stages, serving participants as they enter graduate school and progress beyond, introducing PhD students to others in the field, broadening their network as their careers develop, and arming all participants with self-confidence. The conferences gave mathematicians and their students from across Africa the opportunity to attend, give a talk, and even help organize an international conference.

The conference gave many women additional professional experience, even for women more established in their careers. After meeting at the first conference, one of the participants asked for a letter of recommendation for her promotion case to Professor, and at the second conference she announced that she had, in fact, been promoted. Nancy and Rob invited a participant from South Africa they met at the 2018 conference to come and speak at a Canadian and US combinatorics conference. A year after the second conference, a participant from Ghana asked Karin-Therese to help her co-supervise honors students. Collaborations now exist among women within Africa and across continents, with papers for journal publication currently in preparation. Even we (Karin-Therese and Nancy) worked together in South Africa for three months in 2020 building on the research we had started conducting together from afar. We had started a project at the intersection of our research areas after the first conference, and then Nancy spent a semester working with Karin-Therese as a Visiting Research Fellow at the AIMS Research Centre in South Africa. The pieces are falling into place.

Looking forward

Our goal is to have a strong community of women in mathematics at all stages of their careers that provides support not only for graduate students and new PhDs but also for women throughout their academic and professional lives. We aim to have regular research conferences where women mathematicians and their students can present their work and build their self-confidence in a supportive environment, learn ideas and advice for moving research forward, and form new collaborations. We also want this to be a venue for discussing specific challenges faced by women in mathematics, and women in Africa in particular, where we can bring forth opportunities they might not be aware of yet. And we want to show more men that women are mathematicians—young men in graduate school and men at all stages of their careers—and gain their support as we go forward. They will then move through their careers with this frame of mind.

Two conferences have taken place so far, one over two and one over four days. We think the ideal length might be three days—we will test this at the next conference. As a result of the Covid-19 pandemic, we had to cancel the conference planned for March 2020. To replace the pandemic-cancelled conference, a virtual seminar series from August to November 2020 connected African women in mathematics, many who are isolated from the greater mathematical community because of a paucity of travel funds, with more mathematicians from the greater mathematical community than likely at an in-person conference. Prominent speakers included Eugenia Cheng, Federico Ardila, Nalini Joshi, Carolina Araujo, and Marni Mishna. Involving new mathematicians in addition to those who have attended the first conferences is a hidden benefit to these online events; we can reach many mathematicians who are unable to attend the in-person conferences.

Bringing international speakers to these conferences creates more links between the African women mathematicians and other communities and enriches those communities as well, which will benefit all of mathematics. This is how mathematics advances.

We are just getting started

We have a core group emerging from our first two conferences, an ever-expanding cadre of women in mathematics graduating each year from the AIMS Centres, and future leaders already starting initiatives of their own. What began as a conference has grown into an ongoing initiative that supports and encourages African women in mathematics. We encourage you to reflect on what you can do where you are to advance mathematics, particularly among women and other underrepresented groups in your corner of the world.

We shall close by returning to Sofiat, who finished her PhD at the University of Glasgow in summer 2020. Designing and conducting two-week programming workshops in Nigeria and Rwanda is one of the ways she gives back. She says, “I want to raise an army of intellectuals that are going to contribute to the development of Africa. I am a good example of one such African scientist who was empowered by the opportunities I have been given. This initiative was born out of a strong desire to give back to the community by helping other young scientists in Africa and show them what is possible.”

In Sofiat we have one of the attendees of the first conference organizing something and giving back, and the cycle is complete. As the ripples created by a pebble dropping in

water, the energy is passed on and the movement continues. Each one of us can contribute to such a ripple effect, thereby creating a powerful worldwide community for women in mathematics.

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MAA Project NExT
Community During a Critical Transition

Julie Barnes, Alissa S. Crans, Matthew DeLong, Dave Kung, and T. Christine Stevens

Where to start—opportunity, friendship, community, a way to find my niche? At the beginning of my career, MAA Project NExT provided me with a community and a way to navigate through the mathematical world. —Larissa Schroeder, 2012 NExTer [2]

A community begins

San Antonio. January, 1993. The River Walk sparkled with color, activity, and a diverse crowd. However, the Convention Center, then home to the Joint Mathematics Meetings (JMM), presented quite a contrast. A conference attendee recalls what it was like to be a graduate student at her first JMM: long lines extending from the men's restrooms with no wait times for the women's, crowds of primarily senior, white men standing around the hand-written message board, and a lack of attention to topics other than traditional mathematical research. Unsurprisingly, this graduate student, with a passion for teaching, in no way felt that she belonged.

The early 1990s also presented a time of rapid innovation in undergraduate mathematics education, filled with enthusiasm for active learning and an interest in the use of technology. But, how could these novel developments be implemented broadly across the country, and shared with new mathematics PhDs who perhaps had not experienced these techniques themselves as undergraduates? And, how could the community help these new mathematicians with their transitions from graduate students to full-time faculty members? In the spring of 1993, Jim Leitzel and Chris Stevens proposed a solution to these questions: MAA Project NExT (New Experiences in Teaching).

In its current form, this three-part, year-long program of the Mathematical Association of America (MAA), provides new or recent PhDs in the mathematical sciences with a professional development experience that addresses all aspects of an academic career. The program primarily consists of professional development in conjunction with MathFest and the Joint Mathematics Meetings. Sessions explore topics such as the teaching and

The authors celebrate the twenty-fifth anniversary of Project NExT at MathFest 2019, (from left) Dave Kung, Julie Barnes, Chris Stevens, Alissa Crans, and Matt DeLong.

learning of mathematics, engaging in research and scholarship, finding exciting and interesting service opportunities, and participating in the profession. It helps participants transition from graduate students with a focus on research to their new roles as full-time faculty members with multiple responsibilities.

MAA Project NExT engages the participants, at the outset of their careers, in intellectually stimulating conversations about important issues in the teaching and learning of mathematics and introduces them to a professional community in which those topics can be discussed in a sustained way. It offers tools that will enable them to address challenges in their own classes and at their own institutions while striving to cultivate a broad understanding of their responsibilities as faculty. This helps them to better integrate their roles as teachers, scholars, and advisers.

Leitzel's and Stevens's idea has had a widespread effect on undergraduate mathematics teaching and, arguably more importantly, fostered a vibrant, thriving community within mathematics that has for 25 years helped launch the careers of more than 2000 new PhDs in the mathematical sciences.

Laying the foundation

> *[In] an email message that Jim Leitzel sent me on February 1, 1993, he said that the MAA Committee [on the Teaching of Undergraduate Mathematics] was interested in "developing a support mechanism for 'newly minted PhDs' as they move to their first teaching positions." I sometimes think of this email as an early sonogram of the embryonic MAA Project NExT.* —Chris Stevens's 2008 Leitzel Lecture

The initial idea devised by Leitzel and Stevens in 1993 consisted of providing participants with a one-week conference focusing on new developments in undergraduate mathematics education. Although they wanted this conference to model good instruction-

al practice by being very interactive, they did not explicitly focus on the creation of a community surrounding these issues. In the end, as Stevens says, "Jim Leitzel and I thought we were running a workshop; what we were really doing was building a community." There were several steps—some serendipitous, some deliberate—that led to that outcome.

Their first consequential decision was to abandon the idea of an isolated, week-long conference. They shortened the duration to a 2.5-day workshop and, notably, coupled it with MathFest, where they suspected many sessions would address issues they had planned to include in their conference. Although this decision to pair the MAA Project NExT Workshop with MathFest was prompted by financial considerations, it served as a vital step in community building because it provided the opportunity to welcome the participants into the greater mathematical society.

Happily, in 1993, Bob Witte, a program officer at the Exxon Education Foundation, approached the Mathematical Association of America with an interest in supporting a project focused on undergraduate education. Thus, the Exxon Education Foundation became the original, and for a long time exclusive, funder of the program, and Bob became a de facto, and beloved, member of the mathematical community.

By the time Leitzel and Stevens had finished reading the applications for the first MAA Project NExT cohort, they realized that the Workshop that they had envisioned would not be appropriate for them. Individually, the participants each had much more experience with innovative teaching techniques than Leitzel and Stevens had anticipated, and collectively they knew an enormous amount! The notion of bringing these new PhDs "up to speed" was clearly irrelevant. They stood back and let the participants take whatever they could from the presenters, while at the same time eagerly learning from each other. The fact that participants could, and would, from the outset, learn so much from one another's experiences provided the foundation for potentially the most beneficial aspect of the MAA Project NExT community: an environment that offered everyone the opportunity to question, learn, and share both successes and failures while feeling supported and encouraged.

Leitzel and Stevens imagined the MAA Project NExT Workshop as an intense and intimate experience, and they did not want the participants to feel lost when hundreds (and now thousands!) of others arrived at MathFest. So, for the first MAA Project NExT Workshop in 1994, Leitzel requested that the MAA staff place colored circular stickers, colloquially called "dots," on the participants' and Workshop presenters' name badges, so that they could recognize one another in the crowd at MathFest. Thus, the dots served to reinforce the community created during the Workshop since throughout MathFest, the participants felt comfortable starting a conversation with anyone sporting a dot on their nametag.

Beginning with the second year, there arose the need to distinguish between the incoming and returning cohorts. Thus Leitzel and Stevens began using different colored dots to distinguish participants from different years, which became the seven-year color cycle rotation naming scheme for subsequent cohorts. This custom contributes to vertical mentoring and a sense of camaraderie amongst the color equivalence classes.

Continuing the connections

During the closing session of the first Workshop, Leitzel and Stevens, together with the initial cohort, conceived of the core of the modern MAA Project NExT programming and

community. Knowing that the participants' schedules at the Joint Mathematics Meetings would consist of interviewing for jobs and giving and attending talks, Leitzel and Stevens expressed their reluctance to plan significant, time-intensive sessions for their next gathering. Thus, they proposed only a dinner the night prior to the start of the meetings together with a talk about an issue in undergraduate mathematics education. In response, the participants overwhelmingly indicated their wish for more programming. In particular, they expressed their desire to discuss the outcomes of everything that they planned to try in their courses during the upcoming fall semester. Then they added the pivotal statement: "And we'll organize it ourselves!"

At this point, Leitzel and Stevens knew that they had something very special—not a workshop, nor even a program, but a group of people who would take responsibility for planning their own professional development. MAA Project NExT was not developing the way that they had imagined, but far better than they had ever dreamed! Leitzel and Stevens decided to get out of the way and let the participants guide them in determining what they needed.

Project NExT cohort, Denver MathFest 2018.

Thus, the initial Workshop coupled with MathFest was, and continues to be, followed by the second facet of the program held the following January during the Joint Mathematics Meetings. The program begins with the reunion gathering originally proposed by Leitzel and Stevens, providing the opportunity to maintain and nurture the cohort community. In addition, the current cohort organizes several sessions held during the Meetings. Although originally intended for that particular cohort, since 2014 the sessions have been open to everyone. Choosing and then contacting experienced faculty leaders (typically never having met them!) to serve as presenters in the cohort-planned sessions helps to better acquaint the participants with members of the mathematical community, thus expanding their networks. Additionally the MAA Project NExT "Lecture on Teaching" and the popular dessert reception welcome all conference attendees.

The MAA Project NExT program concludes with a single-day Workshop preceding MathFest the following year, again featuring sessions coordinated by the participants as well as a "graduation" ceremony.

Creating the community

> *I remember attending the Joint Mathematics Meetings and MathFest as a graduate student and feeling as though I was the only person there who didn't know anyone. It seemed as though everyone was bustling around meeting up with all sorts of people they knew, but I never had that network. I would attend sessions but kept quietly to myself and never really felt like I belonged there. MAA Project NExT changed that for me and truly gave me a smaller math family inside the mathematical community that I can connect with!* —Caitlin Krul, 2015

Although Leitzel and Stevens thought of their colleagues as very friendly and welcoming, they found that new PhDs are actually very intimidated by their initial contacts with the mathematical community. When these new members of the profession attend conferences, they often feel lonely and very much like "outsiders." One of the significant achievements of MAA Project NExT was to involve these new faculty in the mathematical community at an early stage in their careers—an involvement that has benefited both the new members of our profession and the profession itself.

One of the ways that it accomplishes that goal is by making MAA Project NExT participants part of a national network that includes people from many different kinds of institutions. New faculty ordinarily work in an environment that offers them few reference points beyond what is done by colleagues in their own departments or at similar schools in the same geographical area. The more than 2000 participants have come from over 800 different colleges and universities in the United States and Canada, representing a wide variety of institutions: public, private, PhD-granting, secular, religious, two-year colleges, etc. Thus, MAA Project NExT offers participants access to information about curricula, technology, teaching strategies, and research practices at an extremely diverse set of institutions. This diversity adds tremendous value to the community.

Building the MAA Project NExT community begins immediately after acceptance into the program, through intentionally designed activities that facilitate the establishment of connections. Prior to meeting at MathFest, participants introduce themselves electroni-

cally, including a "fun fact" that becomes part of a scavenger hunt held during the initial Workshop.

During this intense Workshop, all sessions and activities are intentionally interactive, not only as a pedagogical principle, but also as a way to encourage conversations among the participants. Every room used throughout the Workshop contains small tables for six to ten people, as opposed to a theater-style lecture setup. Session leaders are requested to abide by a "ten minute talk test," meaning that they do not allow more than ten minutes to go by without having the audience interacting in some manner.

The program also includes several small-group discussions by affinity grouping (e.g., research area, MAA Section, or institution type) and features a networking fair providing participants time to learn about opportunities and resources available in the mathematical community, as well as form professional connections. The schedule purposely includes long, regular breaks and meal times to encourage continued conversations with speakers and one another, as well as a reception uniting the current and previous cohorts in which the returners provide insight and advice from their first year. Recently, the leadership team began facilitating the formation of teaching-based subgroups of participants, based on a choice of teaching techniques NExTers plan to try in the upcoming semester. These subgroups then check-in with one another during the semester and share their experiences when meeting again at the Joint Mathematics Meetings. Finally, since the first year of the program, there has been a tradition of housing everyone in the same location, encouraging spontaneous game nights, morning jogs, and ice cream runs.

Most notably, likely due to the fact that the significant majority of participants experience a variety of transitions when they arrive for the Workshop, cohorts bond quickly over a commonly shared feeling, expressed sincerely by Allison Henrich (2008), "[The program] was incredibly valuable since this time in a person's life can feel really lonely and scary."

Maintaining and supporting the community

> *I can recall many times in NExT interactions where brave colleagues spoke of things that weren't going well for them. A particular one on the NExT listserv came from a colleague who was really struggling post-tenure and was asking for help. The message was honest and heartfelt and led to one of the best threads I'd ever read: a warm combination of people saying "I hear you," "I feel that way sometimes too," and "this is what I did when I felt that way." It was one of the best examples of how NExT provides a community for us all that reminds us we are not alone and instead are in this work together, even if most of us work at different institutions from one another. Having a friend you can turn to outside your home department is a key part of academic survival and thriving, I think.* —Matt Boelkins, 1999 [1]

The first cohort from 1994 (the Red Dots), bonded intensely during their first MathFest Workshop and expressed a strong desire to remain in touch. Although people often find themselves reluctant to share their thoughts and experiences (particularly negative ones) electronically, it turned out that the intense face-to-face contact time the participants shared at the Workshop enabled them to feel comfortable enough conversing candidly on an electronic discussion list, the "nextlist." In fact, when asked in 1995 by Leitzel and Stevens whether the e-communication should continue, one of the NExTers remarked,

"Yes, we are strongly planning on our nextlist continuing. (There'd be a riot if it was dismantled.)" Thus the electronic discussion list, or listserv, served to keep the cohort in contact, and remains a primary aspect of sustaining the community for years after their initial gathering.

It is not just those Red Dots who have found the listserv vital. Although the issues change as careers progress, members of all cohorts regularly use the listserv for encouragement and gathering advice and resources related to different types of questions and concerns, such as becoming a department head, changing jobs, or applying for promotion. An early participant remarked, "at any time, day or night, there are dozens of people eager to serve as sounding boards or provide information." Moreover, participants reach out to their community to share challenges and difficulties as well, as described in Matt Boelkins's quote above.

Thus, the community established by MAA Project NExT does not end when the participants complete their year of active participation in the program. Knowing that their network will continue indefinitely makes it more useful to them. In addition to the listserv, recent cohorts have taken advantage of additional online communication tools to both share resources and remain connected virtually.

Another important aspect of Leitzel's and Stevens's original plan consisted of assigning a mentor (later renamed "consultant") to each participant and adding these mentors to the listserv. This had the obvious benefit of giving the participants access to experienced faculty members who could provide suggestions and advice on everything from how to implement a particular teaching technique in the classroom or which textbook to use for a course to how to navigate maternity leave issues. The mentor program also built support for MAA Project NExT within the mathematical community by providing senior leaders the opportunity to form relationships with the energetic new people entering the profession. Simultaneously belonging to a group of supportive peers and an active community of experienced mathematicians enables the participants to continue their growth as teachers and scholars, long after their initial year's participation in MAA Project NExT has ended.

MAA Project NExT of the future

At MathFest 2019, MAA Project NExT welcomed its 26th group into the profession. The cohorts have grown in size from an initial group of 66 to 100 incoming participants in 2019. Jim Leitzel and Chris Stevens could not have foreseen the lasting and influential impact that their idea would have on the mathematical community in general and the MAA in particular.

Even with generous support from numerous sources, the MAA and the program leadership team continue to pursue additional funding avenues in order not merely to maintain but also to grow the program so that any new PhD in the mathematical sciences who wants professional development can participate. In recent years, funding sources have been identified to allow the cohorts to increase from 80 to 90 to 100 strong, with a goal of meeting more of the need (over 160 applied in 2019). However, the cohort growth, though desirable and beneficial to the mathematical community, provides a challenge to maintaining the community aspect of the program while preserving the dynamic of the initial Workshop—that intimate experience envisioned by Leitzel and Stevens. Meeting

these additional people over three days will likely provide a challenge! A critical question for the program, then, becomes: How does it reach its growth goals while maintaining the essence of the program—an inclusive, welcoming, and supportive community?

As the leadership team considers the future of the program, they must continue to diversify the community. There has been intentional focus, increasingly so in recent years, on making the MAA Project NExT community itself more inclusive, especially for faculty of color, and to assist participants in designing and nurturing more equitable classrooms and departments. At the same time our community continues to improve. How can we increase our inclusivity? Our diversity? How can we involve more members of the broader mathematical community? How can we reach faculty not typically included in professional development programs, such as visitors, instructors, TAs, adjuncts, and lecturers (VITAL faculty)? And, how can we best use technology to help address these concerns?

Another issue facing the program concerns the increasing numbers of new faculty that have already experienced excellent professional development, while others have had little to none. What Leitzel and Stevens found in that first cohort—that many new faculty had gained significant experience using innovative pedagogies in graduate school—is even more true now than it was then. This favorable situation may represent a sort of ripple effect that MAA Project NExT has had on the culture of professional development in the mathematical community. At the same time, it remains the case that some graduate schools do very little to help develop the teaching skills of their graduate students. Therefore, designing programming to keep both ends of the spectrum interested (but neither bored nor in over their heads) could prove to be a challenge.

Finally, the periodic rotation of leadership team members will have a significant impact on the future of the program. We must preserve institutional memory and the traditions that made MAA Project NExT an exemplar of new-faculty development programs, while simultaneously allowing for novel sessions and activities and adapting to the changing experiences and needs of new PhDs.

Impact on the mathematical community

> *The NExT program prepared me to be aware of issues of diversity and inclusivity and to never stop thinking about ways to break down barriers for myself and others in the hopes of making our community more welcoming and more diverse.*
>
> —Matthew Pons, 2008

MAA Project NExT participants have greatly impacted the lives of numerous students, colleagues, departments, institutions and organizations. They have been recognized with local and national teaching, writing, scholarship, and outreach awards and honored with invitations to speak at local, national, and international conferences and workshops. They have served the mathematical community by holding diverse leadership roles within the various mathematical associations, institutes, and organizations, and worked to promote diversity in mathematics. In fact, MAA Project NExT participants have become an integral part of the Mathematical Association of America and the overall mathematics community.

MAA Project NExT developed alongside a number of broader initiatives aimed at diversifying the mathematical community, such as various summer programs aimed at

women. All of these efforts have contributed to changing the face of the MAA. Senior members of the organization remember attending national meetings prior to the existence of the program. At that time, they recall, the attendees seemed very homogeneous in terms of their age, gender, and ethnicity. Although there still exists a noticeable need to continue to broaden participation in the mathematical community, there is now considerably more diversity in age, gender, and ethnicity at conferences. Moreover, we have elevated issues of diversity in the programming. While breakout sessions on diversity and inclusion have long been included, since 2014 a plenary session has underscored the importance of these issues. We think that while diversifying the participants is valuable, the greatest impact we have is helping all NExTers be more attentive to these issues.

Creating new communities

> *The communities that we build should be organic, growing out of their local situation and reflecting local needs. They should be integrated, with all features working harmoniously together. They should be diverse, because diversity makes a community more useful and thus more valuable. Finally, their essence should be defined by the people who participate in them.* —Chris Stevens

MAA Project NExT was initially created simply to help new mathematicians learn innovative teaching methods. It quickly became something much bigger—a strong and vibrant community. There is no reason why its benefits should be offered solely to new faculty. Many of the lessons learned over 25 years of MAA Project NExT could help inform programs that reach mid- and late-career faculty as well as VITAL faculty. We strongly believe that the salient features that have shaped MAA Project NExT can be adapted to other groups and organizations.

The first aspect contributing to the formation of the MAA Project NExT community is the actual structure of the program, which provides numerous opportunities for participants to interact with one another and make connections with peers and more experienced members of the mathematical community. Second, the program values and takes advantage of what the participants already know and provides opportunities for them to share their knowledge with one another, helping to build relationships. In addition, since members hold responsibility for major components of the program, this aspect makes the MAA Project NExT workshop their own and strengthens their dedication to the community. For portions of the program organized by the leadership team, a conscious effort is made to listen to the needs of the participants and use these to guide the planning.

From the start, it has been abundantly clear that diversity strengthens the community. MAA Project NExT remains an incredibly valuable source of information, support, and encouragement precisely because it includes people from many different types of institutions throughout the country and, via the consultants, many different career stages. This diversity of the program contributes to a diversity of experiences, which invites an openness to others that in turn creates deeper and more authentic community connections. It also creates a more representative community of educators and helps prepare us for diverse classrooms. Finally, being welcomed into a community can be a powerful force in one's professional life at any stage, and particularly during a time of transition. As new faculty, the participants all have recent experience searching for a job, which is often a

dispiriting process that imparts a feeling of worthlessness. The early groups of participants expressed their excitement and delight to join a community that actually wanted and valued them.

It is our wish that the next generation of graduate students attending a national meeting for the first time will observe lines of equal length at the restrooms, notice a diverse group of people checking messages on their cell phones, and engage in conversations not only about their research, but also their interests in mathematics education and outreach. We pledge to continue pushing the MAA Project NExT community to make sure everyone—including those from groups historically shut out of the mathematics community and those who have not participated in the program—benefits from the inclusive community that has welcomed participants for more than twenty-five years.

Leadership history

The program would not exist without the leaders who have worked with it since its inception. Stevens and Leitzel directed MAA Project NExT from its founding until Leitzel's death in 1998, after which Stevens directed the program until 2009. Aparna Higgins then succeeded Stevens as director and served in that capacity until 2014 when Dave Kung (2000) succeeded her. Over the years, the leadership team has also included Judith Covington (1994), Gavin LaRose (1994), Joe Gallian, Steve Schlicker, and Anthony Tongen (2005). In 2019, the leadership team consisted of director Dave Kung, and associate directors Julie Barnes (1996), Alissa Crans (2004), Matthew DeLong (1999), and Alicia Prieto Langarica (2013).

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Julie Barnes is Professor of Mathematics at Western Carolina University. Her Project NExT experiences helped her organize communities on her campus for untenured faculty and female STEM students and work with various MAA committees.

Alissa S. Crans is Professor of Mathematics at Loyola Marymount University. She is known for her active mentoring and supporting of women, underrepresented students, and teachers at all levels.

Matt DeLong is Professor of Mathematics and Department Chair at Marian University in Indianapolis. He is a recipient of both the MAA's Haimo and Alder awards for distinguished teaching.

Dave Kung earned his PhD at the University of Wisconsin. He serves as Professor of Mathematics at St. Mary's College of Maryland, as Director of Strategy and Implementation for TPSE-Math, and as Director of MAA Project NExT.

T. Christine Stevens was a professor at Saint Louis University when she and Jim Leitzel founded Project NExT. She recently retired as Associate Executive Director of the American Mathematical Society.

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Math Mamas
Navigating Mathematics and Motherhood

Emille Davie Lawrence

Recognizing a need

I belong to several communities of mathematicians. There is the community of "EDGErs" —those who have participated in, mentored for, or served as an instructor for the EDGE (Enhancing Diversity in Graduate Education) Program (I have done all three). There is a supportive community of Black-identified mathematicians whom I can lean on. There is also my cohort of rad topologists that graduated between 2006 and 2008 that I enjoy seeing on the conference circuit. Belonging to each of these as well as other communities has always been and will continue to be an important part of my professional life. However, after I became a mom to Margot and then later Grayson, I began to sense that there was still something missing. Without much warning, teaching and proving theorems took a back seat to changing diapers and wiping tears. Sure, I had help and support from my loving husband Greg who is a wonderful dad, but as a nursing mother, I was literally the source of their survival—day and night. Greg took a few weeks of paternity leave after the birth of each child, but I took a semester plus a summer of leave each time. I am forever grateful for the amount of time I had to bond with each of my children. But quite frankly, all of that bonding left me completely exhausted. Furthermore, I had always been a person who accomplished most of the goals I set for myself. But this mothering thing was a completely different beast. Why wouldn't she nap? Why wouldn't she stop crying? How do I increase my milk supply? There were so many aspects of parenting that seemed out of my own control, and this frustrated me to no end. I was in other groups of mothers that gathered mostly virtually and occasionally in person, but there were never other group members who could fully understand the specific challenges of academic life and new parenthood. So I decided to make the community that I was longing for.

Forming the group

At the start of 2016, my children were two-and-a-half and ten months. It was the time of year when everyone feels optimistic and full of resolutions to change their world. I knew

Emille with her family on Lake Tahoe.

that there had to be other math professionals and mothers like me who were seeking a community to share the experiences of both of those worlds. But how could I connect all of these moms in math? A Facebook group seemed like a natural choice because in early 2016, most people used Facebook—a lot. It seemed like the perfect conduit for the type of community that I was looking to create. But what should I call the group? "Math Mamas" had a nice alliterative ring.

That very day, I set up the group and invited all of my Facebook contacts that I thought would be interested. Within hours, those people invited others to the group, and before I knew it, the group was growing like wildfire. Every person that joined introduced themselves to the group by giving their professional affiliation along with a photo of their children. I watched the group grow as people excitedly introduced themselves and expressed their delight that there was finally a "place for us." By the powers of exponential growth, at the end of the day there were already over one hundred members, and I knew I had tapped into something special. Indeed, there were others like me needing to connect, to belong, to share.

As I write this now, it is more than three years and 800 members later. New members are added to the group by accepting the invitation of an existing member of the group. This works well because these new members have a friend or two already in the group. A potential member could also request access to the group, and I moderate these requests. Once in the group, anyone can make a comment or pose a question, and they immediately have an audience of about 800 other mamas. Any member can comment on or react to any other member's post.

The community that we have created through our shared experiences has been nothing short of amazing. I could have never predicted the impact that the group would make in people's professional and personal lives. We are mothers from each corner of the

country of varying ages, ethnic backgrounds, and academic ranks. However, what we all have in common is our love for mathematics, our love for our children, and our desire to navigate the intersection of the two. We do so by asking for advice, sharing triumphs, and rallying behind one another. I think this is what I love most about our community. If a mom poses a question to the group, there is immediately an outpouring of responses and comments. Furthermore, the virtual conversations show the value of differences of opinion, especially when they are expressed in a genuinely supportive way.

For example, very recently a Math Mama posted about accepting a position at a university in the New York City area, and she was seeking advice on NYC kindergartens for her child. She not only learned useful information about the school selection process in that area, but she also collected helpful advice about the local community. There was also lively discussion surrounding a Math Mama's post about an underperforming student who noted that she couldn't "afford to fail" an online course that she was taking. Some colleagues advised that she reemphasize the guidelines laid out on the syllabus while another Mama brought up the fact that fairness to all students could possibly stand in the way of equity for some. No matter if you agree or not, it is so important to hear and consider these other points of view. The sharing of information with regard to all aspects of working motherhood from childcare grants for conference travel to milk storage to dealing with separation anxiety and beyond has been tremendous. I have learned so much from this community of mothers, and I know I am not alone in that sentiment. One math mama posted the following comment in the group:

> *I think this group is a good example of a horizontal mentoring network where we may all be at different phases in our careers and in motherhood, yet we all contribute to the mentoring relationship.* —Member of Math Mamas

Another math mama noted:

> *I think about this group as a community where I really belong!!!! I wouldn't mind making it known to the whole math community.* —Member of Math Mamas

Extensions of the virtual group

There have also been successful offshoots from the group. In 2018, Jackie Jensen-Vallin, Erin Militzer, and I co-organized a Math Mamas town hall at MAA MathFest. The conversation included a frank and open dialogue which largely centered on the discrepancies among maternity leave policies and the effect they had on career advancement (there happened to be no one in the room to speak about their experience with paternity leave). For example, some people said that their institution allowed them to take an entire semester off with no departmental responsibilities at full pay. Others said they had no teaching responsibilities but had to do some administrative work while on leave. Another mom said that she received no official maternity leave because she was in the first semester at her institution. She graded finals in the two weeks after her son was born. Taken together, this wide range of experiences called attention to the great need for more standardized and empathic parental leave policies.

In February 2019, Rachelle DeCoste, Amanda Ruiz, and I launched the blog "Math Mamas" hosted by the AMS. As editors of the blog, we invite contributors to give readers

a snapshot or even a global picture of their life as a mother working in mathematics. One mom wrote about how she struggled with infertility and how her departmental colleagues showed their support as she went through that tough time. I wrote about leaving a tenure-track position to solve a two-body problem and start a family. These are just some of the experiences shared on the blog that we hope can start meaningful conversations about the ups and downs of working parenthood.

In July 2018, Pamela Harris, Carrie Diaz Eaton, Becky Hall, and I co-edited a special "Math and Motherhood" edition of the *Journal of Humanistic Mathematics*. We published so many fantastic essays, articles, and poems written by women who wanted their experiences as a modern woman in mathematics heard. The authors ran the gamut from those at R1 institutions to liberal arts colleges. Topics included how motherhood can help one be a better mathematician (and vice versa) to dealing with the loss of a child to achieving harmony as a math professor mom and so many more. We even had a mother-daughter co-authored submission on the synergy between mathematics and literature. The issue was well-received. In fact, three of JHM's top ten most popular articles are from the Math and Motherhood special edition.

Challenges

One aspect of starting this community that I didn't expect was grumbling from math parents who aren't mothers. What about math dads? Why not start a group called Math Parents? These are fine ideas, and perhaps other members of the mathematical community will explore these possibilities. I chose to focus on mothers, for one, because women are in the minority in mathematics. There are long-established organizations, programs, and conferences to support women in mathematics. Creating a space that centers on women

Some math mamas gather after the Town Hall Session "Mathematical Mamas—Being Both Beautifully" at MathFest 2018.

in mathematics who also happen to be parents felt like a very natural progression to me. As an added benefit, by and large, people of all backgrounds and genders, parents and non-parents alike, have been very supportive of this community.

Future plans

Ultimately, the growth of the Math Mamas community depends upon the continued interest of the group members. Because we live in a time of internet trolling and cyber bullying, entry into the group is gained by invitation only from a current member. This policy is in place only to help ensure that the group remains a safe space and free from those who don't actually want to contribute in a positive way. Because the community is mostly virtual, it can continue to thrive for as long as people find it useful. There have been small informal Math Mamas gatherings at the Joint Mathematics Meetings and other conferences which can easily continue and expand without adding a financial or scheduling burden. The community has the advantage of operating free from constraints surrounding geographic location or funding. All it needs are people who are willing to share with one another. So far, there has been no shortage of that. Math Mamas represent the mathematics spectrum. As a group, we range from those who hold a bachelor's degree in mathematics to executive directors of national mathematical organizations. There are Math Mamas in business, industry, and government, and there are Math Mamas from all corners of the K–16 system. There are even mothers and daughters in the group. All contributing. All supporting. All listening. All learning something from one another. All doing their part to make our community of Math Mamas thrive.

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From the Diary of a Black Mathematician

Edray Herber Goins and Amy Oden[1]

Birth of "Da Blak Mathimetisian"

The novelist James Baldwin once famously said [1], "To be a Negro in this country and to be relatively conscious is to be in a rage almost all the time." I was fortunate enough to read the works of Baldwin and to learn more about this essayist while I was in high school. My teachers told me how he never felt he fit in: he was a Black man in a racist country, he was openly gay during a time when this was a liability, and he was too intelligent for his own good. And he was relatively conscious and in rage almost all the time. Baldwin was someone I could relate to on many levels.

I decided early in my academic career that I wanted to be a mathematical scientist. I loved science, I wanted to understand the physics of the world around me, and I desired to express it all using the language of mathematics. But I was also an African American male from South Central Los Angeles who had a serious interest in the history of the African Diaspora. My senior thesis focused on the history of the Black churches in Los Angeles, and I wrote a series of award-winning articles for the student paper on the history of the Black students at the California Institute of Technology. However, these two—being a scientist and being a relatively conscious African American—seemed at odds with each other. When I was in graduate school, many of my Black friends would ask, "Can you really express yourself as a Black man while pursuing a doctorate degree in mathematics?" My response was to invoke my e-mail moniker: "Yes—because I am 'Da Blak Mathimetisian'!" (See below.) If only I could find a community where I would fit, one which would accept my Blackness along with my mathematical inclination.

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Edray Goins's e-mail signature from 1994–1999.

[1] This chapter reflects Edray Goins's experiences, written with help from Amy Oden.

Photo courtesy of Mel Currie, *Mathematics: Rhyme and Reason* (American Mathematical Society), 2018.

Outside the Baltimore home of Mel Currie during a break from CAARMS 6 in June 2000, (from left) Edray Goins, Carl Graham, Earl Barnes, Melvin R. Currie, William A. Massey, Ahmad Ridley, and Kathy Lewis.

In the late 1990s, towards the end of my graduate-school years, I learned about the community of Black Mathematicians. I read about the first Conference of African American Researchers in the Mathematical Sciences (CAARMS) when it was held at the Mathematical Sciences Research Institute (MSRI) in 1995 [7]; I would attend for the first time when CAARMS 4 was held at Rice University in 1998. There, I learned about the National Association of Mathematicians, Inc. (NAM), and I met like-minded individuals who would forever shape my world. I found inspiration through the remarkable researchers David Blackwell and J Ernest Wilkins. I found a fellow historian through the topologist Scott Williams. I found a fellow movie buff and Stanford alum through the queueing theorist Bill Massey. I found collaborators through Garikai Campbell, Illya Hicks, Asamoah Nkwanta, Talitha Washington, and Alain Togbé. I found a mentor and father-figure through Mel Currie. I had finally found my community.

Our struggle to find acceptance

My personal struggle as an African American mathematician in search of an accepting community was by no means unique. The National Association of Mathematicians, Inc. was founded with the goal of forming a welcoming community for underrepresented minorities in the mathematical sciences. On Sunday, January 26, 1969, various students and faculty met to discuss how to form such a community. Seventeen individuals at the Joint Mathematics Meetings in New Orleans decided they would no longer let minorities be excluded from the mathematical community. Up to that point, the African American

mathematical community found it nearly impossible to be an active group within the professional societies. Several stories are recounted in detail in [4].

Black mathematicians not allowed banquet tickets

The following events took place in 1951 in the Southeast Section of the Mathematical Association of America (MAA) [4]:

> *The record indicates that African-Americans attempted to attend an annual meeting of the Southeastern Section in 1951, when the meeting was held March 16–17 in Nashville, with Vanderbilt University and Peabody College for Teachers as host institutions. Lee Lorch, the chair of the mathematics department at Fisk University, and three Black colleagues, Evelyn Boyd, Walter Brown, and H. M. Holloway, came to the meeting and were able to attend the scientific sessions. Since Fisk was a private institution, these faculty were not taking quite the risk that faculty at public institutions would. However, the meeting was not without incident.*
>
> *Several days before the meeting, Professor Lorch had requested four reservations to the banquet, which included an address by Saunders Mac Lane, the President of the MAA. On March 15, the day before the banquet, the chair of the arrangements committee, on learning that three of these reservations were to be used by African-Americans, declared the reservations canceled. Thus, the Fisk faculty members could not attend the banquet and hear Mac Lane's talk, "What Makes Students Think?" The request of Professors Lorch and Boyd to President Mac Lane that he withdraw from the banquet or openly state his objections to discrimination at the banquet was declined on the basis that this action would be discourteous to the hosts.*

It will come as no surprise that no African Americans attended meetings of the MAA Southeast Section prior to 1951 [4]. The department chair in the aforementioned story, Lee Lorch, wrote an editorial [2] to the flagship publication of the American Association for the Advancement of Science (AAAS) that same year to announce to the world the racist actions of the professional societies.

Black mathematicians not allowed to publish

Unfortunately, such problems are not isolated to conferences. African American mathematicians were also excluded from conducting research. Indeed, there were powerful mathematicians who were active in keeping Blacks out of the profession. The racist philosophies of the topologist Robert Lee Moore as well as the troubling behavior of the algebraist Saunders Mac Lane are well known within the Black community. These individuals tolerated and participated in a racist culture that derailed the careers of some of the first African American mathematicians.

The first several African Americans who received doctorates in mathematics found it nearly impossible to progress in the field. William Waldron Schieffelin Claytor, the third such African American, graduated from the University of Pennsylvania in 1933. Just the next year, in 1934, Claytor published his thesis in the *Annals of Mathematics*. He applied to work in Princeton at the Institute for Advanced Study in 1935, but ran into problems [10]:

> *… [T]he original idea had been for Claytor to take the [National Research Council] fellowship, in the event that his application was successful, to Princeton to work with*

> *Veblen at the Institute for Advanced Study as well as with the topologists, like Solomon Lefschetz, at Princeton University. Since the Institute then shared space with the university's mathematics department in Fine Hall, the town of Princeton was a topological mecca in the 1930s.*
>
> *It soon became clear, however, that the very fact that the Institute was housed in space owned and controlled by the university closed Princeton as an option for Claytor. In an example of* de facto *segregation, the Princeton University authorities were categorically opposed to opening the university to a black scholar in 1935.*
>
> *The town of Princeton was no more welcoming. Its movie theaters were segregated, and its stores forbade African-Americans from trying on clothes or shoes.*

To add insult to injury, Claytor went to the University of Michigan in 1937 on a Rosenwald Fellowship for several years, but was not allowed to attend research seminars. Although Claytor had the support of his colleagues, Michigan did not offer him a position on the faculty. The Institute for Advanced Study in Princeton may have offered him a position but, by this time, these experiences had combined to change him and he declined the offer. After serving in World War II, Claytor returned to teaching but not research.

Black mathematicians not allowed to learn mathematics

Claytor was not the only topologist who had trouble in the field. Vivienne Lucille Malone-Mayes was an undergraduate at Fisk University from 1950-1955 during the time Lee Lorch was chair of the mathematics department; she received a bachelor's degree in 1952 and a master's degree in 1954. She recalled how Lorch and Evelyn Boyd, the second Black woman to receive a doctorate in mathematics, inspired her to pursue a career in the mathematical sciences [8]:

> *Of the students who were in [Lorch's] department for at least two of the five years he was at Fisk, he influenced one-fourth of them to pursue and earn the master's degree in pure mathematics. Moreover, one tenth of the students continued to the doctorate. … Not even Lorch himself in 1950 could have guessed that students of all colors and ethnic groups in the Sixties and Seventies would benefit so much from his efforts at Fisk in the Fifties.*

Malone-Mayes would eventually pursue a doctorate degree herself. Malone-Mayes decided she wanted to study more mathematics in 1961. Her application to Baylor University in Waco was rejected because she was an African-American. Federal law required the University of Texas to accept African-American students so Malone-Mayes enrolled in summer courses there. Etta Falconer and Lee Lorch recalled that [3]: "In graduate school [Vivienne Malone-Mayes] was very much alone. In her first class, she was the only Black, the only woman. Her classmates ignored her completely, even terminating conversations if she came within earshot. She was denied a teaching assistantship, although she was an experienced and excellent teacher." Malone-Mayes herself recounted that "I could not join my advisor [Don Edmonson] and other classmates to discuss mathematics over coffee at Hilsberg's cafe.… Hilsberg's would not serve Blacks." Even with all of these obstacles, Malone-Mayes became the fifth African American to receive a doctorate in mathematics when she graduated from the University of Texas at Austin in 1966.

Forming community through a common struggle

African Americans seemed to find trouble at every turn when attempting to join the mathematical community: they were discouraged from earning advanced degrees, they were excluded from holding academic positions, and they could not even attend conferences. Walter Talbot, the fourth African American to receive a doctorate in mathematics, lamented that although he began teaching at the collegiate level in 1934, it would be 35 more years before he could participate in the national activities of mathematical societies. He would go on to be one of the founders of the National Association of Mathematicians.

By January of 1969, African Americans in the mathematical community had enough. Not only were they angered by the countless stories such as the ones recalled above, but they were inspired by the political unrest of 1968. In April of that year, Martin Luther King was assassinated, and there were riots at major metropolitan cities all throughout the country. This directly led to the signing of the Civil Rights Act for Fair Housing. In October, Tommie Smith and John Carlos raised their fists in solidarity with oppressed peoples throughout the world at the Summer Olympics in Mexico. Their actions would cause them to be banned from the sport for life. And, in November, a presidential candidate who campaigned on "law and order" as a direct response to protests surrounding civil rights and the Vietnam War would ascend to the highest office in the land. Richard Nixon was the diametric opposite to many Black Americans' preferred candidate, Robert F. Kennedy. By the end of 1968, many African Americans were yearning for change.

There were seventeen individuals who met on Sunday, January 26, 1969 at the Joint Mathematics Meetings in New Orleans to form a new organization. Each had their own deeply personal reasons [6] for wanting to see NAM come into existence and succeed.[2] At this meeting were 60-year-old Walter Talbot, the fourth African American to receive a doctorate in mathematics, and 37-year-old Vivienne Malone-Mayes, who had just received her doctorate a few years earlier in 1966.

Roadtrip to a funeral

I learned about NAM in 2000 at the first Blackwell-Tapia Conference directly from Scott Williams, one of the graduate students who was at that initial meeting in 1969. NAM provided me with opportunities to speak on my research, to learn the history of African American mathematicians, and to enjoy fellowship with those who looked like me. NAM provided me with a community that I did not know existed until well into my twenties. I wanted to give back, so I successfully ran for president in January 2015. I quickly learned

[2] In fact, of the seventeen in attendance, fourteen were faculty and three were graduate students, including faculty James Ashley Donaldson (University Illinois at Chicago), Samuel Horace Douglas (Grambling College), Henry Madison Eldridge (Fayetteville State College), Thyrsa Anne Frazier-Svager (Central State University), Richard Griego (University of New Mexico at Albuquerque), Curtis Jefferson (Cuyahoga Community College), Vivienne Malone-Mayes (Baylor University), Theodore Portis (Alabama State University), Charles R. Smith (Paine College), Beauregard Stubblefield (Texas Southern University), Henry Thaggert (Jarvis Christian College), Walter Richard Talbot (Morgan State College), Argelia Velez-Rodriquez (Bishop College), Harriet Rose Junior Walton (Morehouse College) and graduate students Johnny Lee Houston (Purdue University), Robert S. Smith (Penn State University), and Scott W. Williams (Lehigh University).

that, while there were countless stories of heartbreak and setback, there were many stories of hope and inspiration. I would like to recount one.

In January 2018 at the Joint Mathematics Meetings in San Diego, NAM held its annual Banquet. We bestowed our Centenarian Award to two African Americans who celebrated 100 years of life: Virginia Newell, the author of *Black Mathematicians and Their Works*; and Clarence Stephens, a master educator known for the Morgan-Potsdam Model of teaching [5]. Stephens arrived at and assumed the role of chair of the Department of Mathematics at Morgan State University in 1947. He encouraged students to pursue graduate studies in the mathematical sciences. Some of the undergraduates Stephens taught during this time who went on to earn a doctorate degree are Earl Barnes, Vassily Cateforis, Earl Embree, Gloria Ford Gilmer, Arthur Grainger, Charles Moore, Sylvester Reese, Robert Smith, and Scott Williams. Unfortunately, Stephens passed away just a couple of months later on March 5, 2018.

I decided to contact my friend and fellow historian Scott Williams to see if he was interested in attending the funeral. Stephens passed away in Conesus, New York; the funeral was scheduled to take place in Geneseo, just over 60 miles away from Scott's residence in Buffalo. I flew into Buffalo on Sunday, March 11 in the evening. Scott met me at the Hilton Garden Inn in the early morning on Monday, March 12, and we made a two-hour road trip to Central Presbyterian Church in Geneseo. It was an honor to attend the funeral services as the President of NAM, and to witness the burial with military honors at Temple Hill Cemetery. But the highlight was being able to spend invaluable time with Scott Williams: a founder of NAM, a great mathematician, a master storyteller, and one of the most charismatic people one could ever hope to meet. Even though he was 75 years old at the time, it felt as though I had spent hours on a road trip with a spry thirty-year-old.

The impact of Clarence Stephens is wide-reaching. I could see it in how Scott Williams described his former teacher molding an impressionable young undergraduate at Morgan

Scott Williams and Edray Goins in Buffalo after Clarence Stephens's funeral on March 11, 2018.

State. Later in 2018, NAM established the Clarence F. Stephens / Abdulalim A. Shabazz Teaching Award. But Stephens also instilled in his students the importance of community. I could see this with Scott, and I was humbled to be able to reap the benefits of this community as president of NAM.

NAM Undergraduate MathFest XXIX

In the Fall of 2019, I was able to merge my NAM community with my newfound community at Pomona College. From September 27–29, NAM hosted its Undergraduate MathFest XXIX at Southern University of New Orleans. This three-day conference saw nearly one hundred undergraduates and another twenty faculty members giving talks and attending panel discussions. I convinced two of my Pomona students, Myles Ashitey and Brian Bishop, to make the trek from California to Louisiana for the meeting. They had done research with me the previous summer as part of my NSF-funded REU "Pomona Research in Mathematics Experience" (PRiME). I wanted these students to showcase their talents amongst other talented African American students.

However, Myles and Brian were hesitant to give presentations. They felt they did not know the material well enough to answer in-depth questions, and were not poised enough to represent their advisor adequately. I tried to ease their fears by reminding them that they had already done excellent jobs in presenting their work at MAA's MathFest a few months before, and I instilled new fears in them by jokingly suggesting they would not be able to return to Pomona unless they presented their work. Eventually the two agreed to give a presentation, with the compromise that they would present jointly.

The morning of their talk, they expressed how anxious they were about doing a bad job. Brian was a bit more happy-go-lucky, whereas Myles was on the verge of having a

NAM's Undergraduate MathFest XXIX on September 29, 2019, (from left) Edray Goins, Myles Ashitey, Brian Bishop, and Naiomi Cameron.

panic attack. I looked Myles in the eye and told him he had already proven to me that he was brilliant: he was capable of giving an excellent presentation. By presenting at NAM's Undergraduate MathFest, I continued, he would inspire other African American undergraduates to aspire for excellence. There was no doubt in my mind that he would wow the audience, and there should be no doubt in his either. With that, the two gave a stellar presentation. In fact, they both won a speaking award!

On the way back to the airport, Myles had a huge grin on his face. "Did I make you proud?" Myles asked. I assured him I was always proud of him and I hoped this experience gave him more confidence in his abilities. "You know, Professor," Myles responded, "I'm glad that you made me give that presentation." Since then, I've wondered to myself: Would Clarence Stephens have done the same, as he inspired Scott Williams? Or Lee Lorch, as he inspired Vivienne Malone-Mayes? At least I could take comfort that 'Da Blak Mathimetisian' was remembering his history, and making an effort to ensure that other Black mathematicians felt accepted into the mathematical community.

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21

Fostering a Community of LGBTQ+ Mathematicians

Christopher Goff, George Bradley, Alexander Hoover, and Aubrey Kemp

Trying to tell the story of Spectra, the Association for LGBT mathematicians is a daunting task, mainly because it isn't complete yet. While the *Notices of the American Mathematical Society* (AMS) recently published a wonderful article [2] detailing the historical background behind the creation of an "official" group for LGBT mathematicians, and while examples of our stories have also been shared in some recent Mathematical Association of America (MAA) venues [4], we are still very much in the process of building our community, finding our way, and moving towards becoming the inclusive, supportive group we want to be.[1]

As with building any community, there are inherent difficulties. Even the acronym, LGBT—referring to lesbian, gay, bisexual, and transgender mathematicians—leaves out some people who we want to include, such as asexual, genderfluid, intersex, and more (which we will denote LGBTQ+), as well as people who are allies to these groups. And lest you think that we are simply being overly pedantic to mention all these differing groups of mathematicians, the fact is that language matters. If we forget or leave out a group of people, we may indicate or at least inadvertently imply that those people are not important. We explicitly want to be inclusive, especially since today's society continues to recognize a growing number and scope of identities that lie outside of "heteronormativity." In addition, we certainly chose the word "for" in our name to mirror the Association for Women in Mathematics (AWM). Just as one doesn't have to identify as a woman to be "for women," one does not have to identify as LGBTQ+ to be supportive of those who do.

What follows below are testimonials from four members of Spectra: Christopher Goff of the University of the Pacific, George Bradley of Duquesne University, Alexander Hoover of the University of Akron, and Aubrey Kemp of California State University-Bakersfield. We are at different points in our mathematical careers, and we bring a variety of experiences and perspectives. But it is our collective hope that by sharing these personal

[1] See the *Notices* article for more information about some of the events mentioned in this chapter.

stories we can convey the extremely important role that fostering our mathematical community has played in each of our lives.

Lifting our voice (Christopher Goff)

Like some epic poems of old, I feel like this story is starting *in medias res*—in the middle of things. I hope I can provide an honest look into some of the decisions made and actions taken to create a new community of mathematicians, as well as a glimpse of where Spectra is headed in the future.

The way I see it, Spectra has arisen organically, from its humble beginnings hosting regular social gatherings to its attempts to gain more formal recognition, engage in meaningful programming, and build a lasting underlying structure. Back when the MAA started its Special Interest Groups (SIGMAAs), a small number of us applied to become a SIGMAA for LGBTQ+ mathematicians. This effort failed because the proposed community was not tied together by a common mathematical basis, a requirement for SIGMAA formation. This highlights one of the fundamental challenges to building this Spectra community: our point of connection is not based in a certain topic or field of mathematical knowledge. Rather, we span all aspects of professional mathematical life, from our identities as tenured and tenure-track faculty, visitors, instructors, postdocs, researchers, graduate students, and undergraduates, to our workplaces at research institutions, smaller public universities, private schools, government agencies, and industries. But Spectra's social events benefit from having access to this kind of membership scope. Indeed, our annual on-site receptions at the Joint Mathematics Meetings (JMM) usually bring in at least sixty attendees, if we count all the members, allies, and professional society leaders that stop by for camaraderie and refreshment.

We also have an annual tradition of hosting an off-site reception at a local bar or restaurant that caters to LGBTQ+ patrons. This began as a way for some JMM-goers to be able to meet like-minded individuals but also to keep their own identities hidden. The proverbial closet can be very real, and while the off-site reception option was perhaps even more important back in the late 1990s when it began, at the time of this writing only twenty-two states protect both public and private employees from discrimination on the basis of sexual orientation, gender identity, and gender expression. In order to accommodate members who are at different stages in their own coming-out process or are employed in inhospitable work climates, we continue the tradition of identifying a time and place to meet away from the JMM crowds. However, here too lies a potential drawback. Often the most convenient of these establishments are bars catering to a largely gay male clientele. As such, we know that some Spectra members choose not to attend for a variety of reasons, especially if they are not gay males or they do not drink alcohol.

As a gay male who does drink alcohol, I often attend both receptions. The social aspect of Spectra is what drew me to the group. Indeed, I feel very fortunate to have attended the first reception in San Francisco back when I was a graduate student at UC Santa Cruz, a very accepting institution in a very accepting state, as I was just beginning my journey of coming out. When I go to events now, it's nice to meet new people at the receptions (both on-site and off) and find out where they work, where they went to graduate school, who their advisors were, and what mathematics they are working on. I especially look forward to reconnecting with friends each year, some of whom I met at that first reception.

For that reason, when George Bradley (whose testimonial follows below) decided to step down from his role in planning the on-site receptions, I volunteered to take it over. My task was made easier because many people pledged annual donations towards continuing the receptions. Fortunately, this was also when we garnered a somewhat "official" status, becoming a "mathematical caucus" within the National Organization of Gay and Lesbian Scientists and Technical Professionals (NOGLSTP). As a charitable nonprofit (501c3) organization devoted to supporting LGBTQ+ professionals in scientific disciplines and technical industries, NOGLSTP (which now goes by the name Out to Innovate) also helped us tremendously by providing financial support as well as a secure and professional way for our members to contribute to the onsite receptions. Hence Spectra took another baby step towards its current incarnation.

While the social aspects of the Spectra community drew me in and got me involved initially, I have also appreciated our more recent efforts to expand the organization into offering programming at the JMM. Our first sponsored panel discussion took place at the 2015 JMM in San Antonio with "Out in Mathematics: LGBTQ Mathematicians in the Workplace." Because of the recent efforts of new members like Alexander Hoover (whose testimonial follows) and others, Spectra recently co-sponsored a panel with the AWM at the 2020 Denver JMM, discussing issues that queer families face, including how those issues may differ from those of heterosexual families. For the same JMM, newer and older members of Spectra put together another panel on ways to support transgender and non-binary students. This panel not only demonstrated the range of identities present within the transgender and non-binary communities, but also allowed space for those marginalized members of the mathematical community to be heard. With these panels, Spectra is responding to its members' experiences as well as national trends, and it even helps us recruit new members (like Aubrey Kemp, whose testimonial follows). I hope that attendees gained new insight into some of the challenges faced by LGBTQ+ mathematicians and students.

Another step towards building a community involves representation in the organizational structures of our various professional societies. Spectra members spoke to the MAA, who responded by adding a seat to its Council on the Profession. I was the first to hold this position, the At-Large Member for Inclusion. Among other activities, this allowed me to liaise between Spectra and the MAA, sharing information and advice in both directions.

Spectra is evolving. As mentioned in the beginning, we are in the middle of things right now. We hope to decide on a board structure, a list of officer duties, policies for officer elections, and standing committees. We are working towards creating a fully-formed, established community of mathematicians, but we are still growing. We try to support our members through hosting social events and offering programming at the JMM that can help all mathematicians. We also strive to communicate within our membership to determine what kind of organization our members want us to become. It's an exciting time.

Providing a space (George Bradley)

My involvement with the MAA predates, by many years, my own coming out and becoming a part of the LGBTQ+ mathematical community. As an undergraduate student

at Allegheny College, most of our professors were active in the MAA both nationally and locally. We attended all of the section meetings while I was at Allegheny; I gave a talk my senior year. We were also taken to the national meeting in January of 1975, my junior year. These experiences and the caring nature of the faculty at Allegheny made me hope to one day become a professor of mathematics myself.

After my graduate work at Notre Dame, I returned to the Allegheny Mountain Section when I was hired at Duquesne University in Pittsburgh. The faculty at Duquesne were also very involved in the MAA and I became active in our Section right away. Eventually I became an officer in the section and served in many positions, including governor, newsletter editor, and codirector of short courses. I wrote about my experiences in *MAA FOCUS*, the MAA newsletter [1].

My own coming out as a gay man was intertwined with the beginnings of my part in the formation of the group which has evolved into Spectra. Coming out was a struggle for many of us born in the mid-1950s. We had no gay role models. Homosexuality was at best not discussed and at worst openly ridiculed. Many of us stayed in the closet or, like me, were in serious denial. I met my now husband, Joe, in February of 1996 not so long after I came to accept that I was gay, and after we moved in together, I saw a need to be affirming about my sexuality both personally and professionally. Duquesne is a Catholic school and I was not sure how I would be accepted. Thankfully, there was never a problem for me because of my sexual orientation. I started to connect with other LGBT mathematicians at national meetings.

Offsite receptions for the LGBTQ+ community had started in the late 1990s. A listserv had been started for LGBT mathematicians so we had some contact outside of meetings. A small group of mathematicians met together at the Joint Meetings in 2001 and decided that we needed to be organized. Many LGBTQ+ mathematicians were discriminated against or even fired from their institutions and many had to remain closeted. We knew we needed a group to support each other and a place at meetings where we could meet comfortably and securely with others in our community. It was a good opportunity for networking and learning about institutions that were LGBT friendly and supportive (as well as those that were not). We decided we would meet as a group at each national meeting and have a reception onsite for LGBTQ+ mathematicians and friends at the Joint Meetings. This would be a time for all LGBTQ+ mathematicians to make new friends and contacts and socialize in a stress-free environment. For the first twelve years, I made all the arrangements for the reception. The MAA and its officers were very supportive right

from the beginning and gave some financial assistance. I was Governor of the Allegheny Mountain Section at the time of the first onsite reception in San Diego and made an announcement of the reception at the Governor's meeting. The reception was very well attended, and the MAA Executive Director, President, and several other officers came to show their support.

Being part of the LGBTQ+ mathematics community helped me immensely in both my personal and professional growth. My leadership roles in the formation of the group that eventually evolved into Spectra and my responsibility in starting and organizing the onsite receptions for LGBTQ+ mathematicians and friends made me much more comfortable in taking other leadership roles in the MAA at both the local and national levels. It gave me another community that I was happy be part of and serve. It gave me a place where I could truly be myself.

I had a lot of baggage growing up and living for some years as a gay man, first in denial and then closeted. My life would not have been nearly as happy or fulfilled had it not been for my involvement in and sustained growth of our organization.

Playing an active role (Alexander Hoover)

Learning what it means to be a part of a community and what role you can play in it is not always easy. It can be especially difficult in one that relied on silence for so long as a form of survival, as it has been for many members of the LGBTQ+ community. As we're writing this, we just hit the fiftieth anniversary of the Stonewall Riots, and, while LGBTQ+ folk did not appear out of the ether in 1969, we have had only fifty years of modern struggle and evolution to form a community that cuts across race, gender, and socio-economic class. Furthermore, every generation comes with different points of reference. I was an out queer teen who remembers constitutional amendments that were passed in my home state of Ohio and how gay marriage continued to be a strong wedge issue to turn out voters against the LGBTQ+ community up until the year I graduated from my doctoral program in 2015. Though political advancements in terms of LGBTQ+ can be frustratingly slow, society has evolved; people growing up today have a relatively broad range of liberty to express their LGBTQ+ identity. Having this evolution in culture reflected in one's professional life is a more ambiguous story.

When approaching the idea of the LGBTQ+ community in mathematics, I first have to reflect on my own journey. As of writing this, I just finished my first year as a tenure-track professor at the University of Akron. I've been out to my colleagues and academic institutions for the entirety of my academic track, but I remember the initial caution that dictated my actions. I was a bit reticent to put my identity out front and center in full view of a fairly homogeneous (i.e. white, male, heterosexual) power hierarchy, no matter how liberal an institution may appear. When there are few visible figures of power that are representative of your community, one possible response is to just keep your head down and quietly move forward.

Perhaps this reticence to be out front and center is one of the challenges of being queer in math (here I'm using queer as a general term to describe the LGBTQ+ community). There is no 'queer' math, like the queer subfields that can be found in the social sciences and humanities, just queer mathematicians. In math and academia as a whole, this

reticence can manifest itself out of fear that somebody down the line with power over you could hamper your career, even vote to deny you a job or tenure. When one goes on the job market it is fairly easy to find the ads of a number of potentially hostile institutions that would not want a queer faculty member. Furthermore, it doesn't help when you have other members of the LGBTQ+ community telling you to avoid mentioning any part of your queer identity in your job applications for fear of reprisal.

I ultimately did not take this advice, but there are still difficulties in figuring out what to do after coming out professionally. Before becoming a part of Spectra, I found very few resources that were easily accessible for me, especially as an applied mathematician who did not attend the JMM.

My "community" at this point was a mental list of LGBTQ+ people whom I'd met at academic conferences. Many of us were frustrated that the mathematical community didn't acknowledge our problems or concerns and we didn't know how to effect change. The LGBTQ+ population is still not acknowledged by the United States Census, but polls and other methods estimate that we make up five to ten percent of the population, with the younger generations more comfortable identifying as LGBTQ+. STEM retention is an issue, where LGBTQ+ students who start in STEM are less likely to stay in STEM than their heterosexual counterparts. Understanding how to create an inclusive space for LGBTQ+ students and faculty is essential to combatting this discrepancy.

My academic life changed when I attended my first JMM when I was on the job market in 2018. I had read about Spectra when looking for other LGBTQ+ mathematicians online and joined their mailing list. I saw that they had a few activities scheduled for the meetings, such as an on-site reception, a board meeting, and a panel on inclusivity.

The board meeting included a mix of students, professors, and other early career professionals, like myself. The members of the Spectra board had been working to grow the scope and presence of the organization and were open to new ideas. The meetings allowed us to have a dialogue with each other in a way that would not be completely possible in each of our academic silos. These discussions leveraged both the experience of the older members of the community and the fresh perspectives of the new generation of LGBTQ+ students. From this meeting I also learned about the importance of being out and present on campus. The members of the trans community were vocal about needing to know that they have allies and role models who they can rely on for support. The trans attendees of the board meetings talked about the difficulty and loneliness of being in a department that didn't know how to or care to create an inclusive environment. Having them present at the board meeting was a potent reminder of the importance of being an engaged member of the community, rather than a professor who "happens to be queer"—an easy out for many people. It also drove home the importance of nurturing inclusive environments within departments and how organizations like Spectra can address the issues of all members of our community.

After this meeting I decided that I had finally found a professional community where I could play an active role. During the meeting I volunteered to help run a town hall at JMM 2019 in Baltimore where a host of LGBTQ+ issues would be discussed and members of the audience were free to attend and discuss their viewpoints. The town hall sparked new topics for future discussion. At home as an assistant professor, I feel myself maturing

into a new role in my local community. I try to foster a welcoming environment in my classes and ask for pronouns and chosen names. I've made myself available to the local LGBTQ+ student groups and have offered to help the Pride in STEM student group on campus by talking about my experiences and the available resources.

With the MAA and AMS no longer meeting jointly at the JMM, Spectra is at a crossroads. What was begun as an informal gathering at the JMM in the 1990s has now lost its anchor, but we're left with an opportunity to expand in scope. There's no reason that Spectra can't organize at other conferences, form student chapters, and become a coordinated network of LGBTQ+ mathematicians who can discuss the issues that affect our community and our response to it. Though the future isn't fully planned, I believe in the strength of the community to adapt and grow.

Empowering unique perspectives (Aubrey Kemp)

It wasn't until I was about 25 and towards the end of my program in graduate school that I began to question my sexuality. I should say I began to question consciously (after serious reflection, I have always questioned it, but had no idea it was happening). Thus, I was questioning when I began to apply for jobs in academia. As someone with impostor syndrome (which could stem from several things, one of which is certainly being a female in mathematics), talking myself up in applications was a difficult task. After some moments of panic in the application process, I was offered a wonderful job and am about to enter my third year in a tenure-track position. That is not to minimize the personal crisis of not being able to articulate my full identity while advertising myself to people I did not know. I had no idea if I was applying to places where I would be accepted or places where, if they were to find out I was queer, they would not want to hire me, promote me, or associate with me at all. Even if the school and faculty were accepting, what if most of the people living in the city were not?

While my PhD is in mathematics, my research is in collegiate math education, and I am a member of the SIGMAA on Research on Undergraduate Mathematics Education (RUME) community. The 2019 Conference on RUME was scheduled to take place in Oklahoma City, but in June 2018, Oklahoma was added to the list of states in Assembly Bill 1887 in California which prohibits California from approving state-funded or state-sponsored travel to certain states that have enacted laws that discriminate based on gender expression, gender identity, and/or sexual orientation. Although the 2019 conference was still in Oklahoma and many members were not able to attend without paying out of pocket, the Executive Committee and the local organizers (and many people in the community) planned for the conference to have all (or almost all) gender neutral bathrooms, a panel with all LGBTQ+ members, open table talks about LGBTQ+ issues, places to write experiences, comments, and questions to help facilitate discussions during breaks. It was the first conference where I felt like I could talk openly about my professional and personal life at the same time. Despite hearing a few whispered comments like "I don't see a need for a focus on LGBTQ+ issues at a math conference," I felt like my full self for the first time in a professional setting. This push of confidence helped me to come out professionally to my colleagues, people already in my life, and people I would meet from that moment on. I will forever be thankful to the RUME community for not only taking action

in this situation, but for continuing to work towards inclusion by presenting opportunities to hear experiences and learn from members of several underrepresented groups.

I attended MathFest in 2019 as part of Project NExT and met a lot of wonderful people, many of whom are in the same stage of academia, and therefore can celebrate and also commiserate over the experiences that come along with it. As a subset of these wonderful people, I met several who identify as members (or allies) of the LGBTQ+ community. One of these people is Alex Hoover, who subsequently introduced me to Spectra. I was immediately interested in learning more about the organization and participating in any way I could. At the 2020 JMM I attended many of their events, including the on-site reception, off-site reception, the panel on LGBTQ+ families in academia, and the panel on how to support our transgender and non-binary students. The receptions allowed me to meet so many LGTBQ+ mathematicians and allies and provided a space where we could feel truly comfortable. The panel for LGBTQ+ families in academia provided meaningful conversation and resources for how to find LGBTQ+-friendly campuses and faculty, among other things. (I cannot emphasize enough how much less anxiety I would have felt if I had attended that panel before I was applying for jobs.) Finally, the panel for transgender and non-binary students was the most insightful panel I have ever attended. This was the first time I had heard of an event solely focused on illuminating the experiences and voices of transgender and non-binary people in the mathematics community. I learned about obstacles I had never considered before, perspectives I had never thought about, and so many ways to continue educating myself on how to better support my students and colleagues. Spectra provided a space for a group of students and faculty to have their voices heard at a major conference and to share their experiences, concerns, and support. If this community can help me continue to learn and feel empowered, I can only imagine the positive impact for people who have dealt with even more opportunity gaps in life. This brings me to my next point(s).

My path is not representative of the trauma experienced by so many in the LGBTQ+ community. I am a white, middle class, cisgender female who [usually] presents as straight. I have an extremely supportive family, I never had to worry about access to resources, and I never dealt with overt anti-LGBTQ+ discrimination (at least in a personal way—of course there are many ways in which discrimination against the LGBTQ+ community occurs). In terms of writing this piece as a member of the LGBTQ+ community, there are many other voices that could be considered before mine. However, since I am being given this opportunity, I would like to use this platform to focus on members of groups whose voices are at more of a threat to be silenced than my own.

Intersectionality, a term coined by Kimberlé Crenshaw in 1989 [3], was established to describe the ways in which both race and gender interact to form unique experiences for women of color. The idea of intersectionality has evolved to now include sexuality, class, ability, and other things in addition to race and gender. Re-affirming some of the unique challenges faced by transgender mathematicians and students that were shared at the Spectra panel, Autumn Kent (a trans woman in math) was interviewed about her experiences in a Q&A[2] in 2017. In this interview, she elaborates on concerns in academia such

[2] See blogs.scientificamerican.com/roots-of-unity/q-a-with-autumn-kent/ for the interview.

as access to gender neutral bathrooms, access to the health care transgender people need, publishing or applying to jobs with a name that differs from a dead name, and general intolerance. She also emphasizes the importance for us to listen to women of color and trans women of color. In presenting these ideas, I remind myself words only take on purpose when there is action tied to them.

Moving forward (Christopher Goff)

These testimonials show that each of us has found our community in Spectra and each of us has worked to expand its scope. There are many other members of Spectra, well over 400 at the time of this writing, and it continues to grow. Perhaps that's why Spectra feels like a work in progress: there are so many voices coming together to create this organization, so many people working to incorporate their own identities into a professional mathematical association.

There are, however, challenges that are inherent in any similar identity-based grouping of mathematicians. I mentioned earlier the vast scopes involved: member identities that span a variety of sexual orientations and gender identities, not to mention genders, races, ethnicities, nationalities, etc.; member positions that range from undergraduate students to a former president of the AMS; and members whose disciplines span all kinds of pure and applied mathematics, and whose other professional organizations include not only the MAA, AMS, and AWM, but also the National Association of Mathematicians (NAM), the Society for Industrial and Applied Mathematics (SIAM), and others. While that kind of scope is incredibly helpful for garnering attendance at social events, it makes inclusivity in programming more difficult. And since inclusivity is paramount to Spectra, any lack of it, whether real or perceived, is a problem. For instance, the leadership of Spectra is currently largely comprised of cisgender gay men, and cisgender gay men have written three of the four testimonials presented here. We are not quite sure why women and transgender people are underrepresented in Spectra—it may be related to the underrepresentation of women in mathematics in general or it may be that women put their volunteer bandwidth towards AWM and other worthy organizations. The current leadership is still figuring out how best to tap into all the other potential Spectra members. We know that having more participation from women and transgender people would help guarantee that their perspectives are brought to the table, but we still struggle to make it happen. To me, this is currently our greatest challenge.

Despite these challenges, and in response to them, Spectra will continue to evolve. From its early days as a social group formed in resistance to homophobic and transphobic legislation, to joining NOGLSTP, a national umbrella group for LGBTQ+ scientists, to offering social events and programming at the JMM, Spectra will find a way to move forward. The LGBTQ+ community often talks about the "family you choose"—since many are sadly disowned by their biological or legal families once they come out as LGBTQ+. These are the close friends whom you gather around you, who support you and whom you support in your daily lives, and who provide deep, lasting friendships. I'm happy to say that Spectra has become part of my chosen family. I look forward to seeing what kind of community we become.

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Christopher Goff is Professor of Mathematics and Director of General Education at the University of the Pacific in Stockton, CA. He also serves as a director of the Euler Archive, an online repository of most of Leonhard Euler's original works.

George Bradley received the Allegheny Mountain Section Distinguished Service Award given every five years, the annual service and teaching awards given by the Section, and College and University teaching awards during his 37-year tenure at Duquesne University in Pittsburgh. He chaired the MAA Committee on Minicourses and served on several other national and section committees.

Alexander Hoover is Assistant Professor in Mathematics at the University of Akron. He identifies as a queer applied mathematician, and, when he's not creating models to understand the world around us, he reflects about how to empower the community around him.

Aubrey Kemp is Assistant Professor in the Department of Mathematics at California State University, Bakersfield and her research is in collegiate mathematics education. She enjoys learning about student understanding of mathematical concepts, how students' identities shape their experiences, and ways to be actively anti-racist in the classroom.

22

The Community of AIM SQuaREs

Estelle Basor

Overview

The American Institute of Mathematics (AIM) was founded to advance mathematical knowledge by fostering collaborations among diverse groups of researchers. AIM's primary scientific programs are week-long, focused workshops and small research groups called Structured Quartet Research Ensembles (SQuaREs). Approximately 750 mathematicians per year visit AIM for either a workshop or a SQuaRE.

The SQuaREs program supports collaborations of four to six researchers to work on hard and interesting mathematics. Unique among all the mathematical institutes, this program allows not only for small groups to work together, but also for repeated visits and intense collaboration. Most often the groups meet three times over a three-year period for a week each time. While these groups are each individually very small communities, they together make up a broader community of AIM SQuaRE participants.

Often we host four or five SQuaRE groups at once. On Monday morning we ask participants to introduce themselves and tell us something about the mathematics of the SQuaRE. Participants from other SQuaREs frequently ask questions about the mathematics, and one SQuaRE group may discover that a participant from another group may be helpful to them during the week. For AIM staff, listening to the wide variety of mathematical topics and sensing the enthusiasm in the participants is one of the most interesting and enjoyable parts of the week.

Participants in a SQuaRE are provided with full funding for travel, hotel, and food while they're at AIM in San Jose. Reservations and logistics are handled by the AIM staff, and they have use of a seminar room during their visit. Participants share breakfast together each morning, eat lunch together at a large table in a cafeteria, and enjoy happy hour together each evening. On Tuesday evening, there is a joint reception for the participants. Some SQuaREs return to AIM at the same time the following year. Other times the SQuaREs are entirely different groups.

A brief history

In keeping with our goal of increasing collaboration and advancing mathematics, AIM initiated the SQuaRE program in the fall of 2007. The original motivation for the SQuaRE program was to provide the means for researchers to continue collaborations that began at AIM workshops in a more organized fashion. However, many of the SQuaRE groups are new collaborative efforts that have arisen independently of the AIM workshop program.

We have hosted over 370 SQuaRE weeks since our program began. In the first few years of the program we accepted only six to ten new SQuaRE projects each year, thinking that our steady state would be about 30 groups per year. But as the program gained in popularity, we increased the number so that now we are closer to 50 to 60 SQuaRE groups each year. These groups are funded by our institute grant from NSF and also with supplemental funding from the Simons Foundation. The program is highly competitive with an acceptance rate of about 25 percent.

The AIM Scientific Board selects both workshops and SQuaREs. The proposal for a SQuaRE includes the names of the participants and a description of what each might contribute to the project. Often we find that a couple of the participants have worked together before; other times the participants know of each other's work, but have never met in person. Sometimes, someone has the idea that it would be beneficial to have these particular people work together. The AIM staff suggests to a new group that they use some time for planning and organizing their future visits to AIM to help the community evolve and grow.

Some highlights

The rich and varied topics of SQuaREs range over many areas of pure and applied mathematics. While significant progress on research problems is the most common outcome of a SQuaRE, there are other important consequences of a SQuaRE collaboration.

Over time we have noticed that the SQuaRE format provides a particularly good way for junior and senior faculty to interact. On average, a SQuaRE group produces about one paper per year. For junior faculty, this can help lay the foundation for a good solid research program. When choosing SQuaRE projects, we pay particular attention to diversity. Many of our SQuaRE groups consist entirely of women and have their beginnings

Photo credit Sonya Kohli of the American Institute of Mathematics.

SQuaRE participants at AIM.

in other communities that support diversity, such as Women in Numbers. We encourage faculty from non-research schools to apply for and participate in SQuaREs. We have also noticed unusual blends of expertise at SQuaREs. The group may, for example, have mathematicians and medical researchers. The format allows for these individuals to interact in real time, face-to-face, and to make real progress.

To illustrate some of the topics and outcomes, here are some highlights of past SQuaREs.

- The SQuaRE **Understanding the mathematical underpinning of medical imaging** was an example of how a unique set of participants can come together. The members of this group included experts in convolution gridding, sampling, coding, numerical analysis, and neuroscience. The SQuaRE group considered how data inherent to the scanning process, such as resonant frequencies and signal decay rates, which are currently used only to provide contrast, can be useful in diagnosing a condition or measuring a response to treatment. Much more information can be extrapolated from the same scan: temperature, blood flow, diffusion, structure, and physiology, for example. Their goal was to develop nonconventional image reconstruction techniques to get this information faster and better than has ever been possible before. It is not an exaggeration to say that the outcome of this SQuaRE will someday save lives.
- The SQuaRE, **New connections between link homologies and physics**, consisted of mathematical physicists, experts in topological recursion, and a number theorist. The main purpose of this SQuaRE meeting was to find new homological theories for knots and links and analyze their properties through new perspectives. These new perspectives include understanding new superpolynomials (knot and link invariants) and developing computational tools to derive explicit forms for them. Various algebraic curves associated to knots arise as classical limits of recursion relations for knot polynomials and in some cases, recursion relations for knots encode information about invariants. This SQuaRE was led by a senior mathematician and had several young, junior members.
- Multiplying matrices is among the most frequently performed algorithmic tasks in the world: it is the workhorse of scientific computation. Understanding the complexity of matrix multiplication is a central question in algebraic complexity theory that has led to new insights and conjectures in the representation theory of finite groups and the algebraic geometry of tensors. In the SQuaRE **Fast matrix multiplication via representation theory of finite groups**, the goal was to find new ideas for matrix multiplication algorithms using ideas from representation theory. The naïve method of multiplying two n by n matrices takes $O(n^3)$ steps. The best lower bound known is $O(n^2)$ since any algorithm must at least read all $2n^2$ entries of the input matrices. Currently the best algorithm known takes $O(n^{2.373\cdots})$ steps. Closing this gap is a major open problem in algebraic complexity theory and is the ultimate goal of this SQuaRE.
- An example of a very applied and practical SQuaRE was **Mathematical modeling, simulation, and optimal design for agricultural water management** that brought mathematicians, engineers, and a numerical analyst together to try to help solve some of the water issues California growers face. The SQuaRE had its beginning in a

"Sustainability Problems" workshop that had representatives from Driscoll's Berries. The goal was to devise planting strategies to reduce water use and maintain profit. The SQuaRE group has now incorporated recharge basin models into their program and now has a very robust program that includes almost all important variables for the decision making process. The work of this SQuaRE and a previous workshop became the subject for an NSF "Science Nation" video, which was featured on the NPR Science News Hour website.

- The SQuaRE **Computations with explicit reduction theories** focused on computing the cohomology of the general linear group of rings of integers of quadratic fields, with the hope of computing higher K-groups. The group had remarkable success. For many specific cases, they computed the ranks of the cohomology, made progress in computing the K-groups, and as a by-product of their first paper, developed a new conjecture relating the Euler characteristic of the associated locally symmetric spaces to class numbers. They wrote three significant papers and commented that "Those of us on the computational geometry side learned about automorphic forms, L-functions, and their connections with the cohomology of arithmetic groups. Those of us coming from the automorphic forms side learned about state-of-the-art techniques in the study of perfect forms and computational geometry. We established new research connections that allowed distinct research groups to form a greater whole."
- Wolbachia is a reproductive parasite that infects arthropod species, including mosquitoes, all over the world. The parasite interferes with the reproductive mechanisms of its host, for example inducing cytoplasmic incompatibility and male killing. What if this common infection could be used as a biological control tool to fight mosquito-borne diseases, such as West Nile virus (WNv)? This idea was the focus of the SQuaRE, **Wolbachia infections in mosquitoes carrying West Nile virus.** The main goal of the project was to theoretically investigate this possibility for West Nile virus, via introducing and analyzing a 12-dimensional dynamical system. Notably, the expression obtained for the basic reproduction number suggests that the Wolbachia infection substantially reduces WNv replication in mosquitoes, and that WNv will be eradicated if at the steady state the overwhelming majority of mosquitoes are infected with Wolbachia.

Participant reactions

The participant reaction to SQuaREs has been overwhelmingly positive. The most frequent comment is that the SQuaRE program allows for participants to work together in person for a week at a time and that there is absolutely no substitute for the person-to-person interaction despite the myriad of electronic means of communication available for long distance collaboration. Another frequent observation is that the SQuaRE program allows for participants to return, and the need to plan for a second or third year of a SQuaRE is a great incentive to keep a research program alive. The repetition of the SQuaRE week really binds the participants as a small community. Here are some common reactions from participants.

For me, the SQuaRE program has led to some of the most productive weeks in my career by far. The opportunity to work in a focused environment, without distractions—

and especially to collaborate with more senior colleagues in such an environment where they are not distracted by other responsibilities or projects—is truly invaluable. Taking part in this SQuaRE has had enormous value to me both in the results it produced and in the collaborative relationships it fostered.

I find the SQuaRE program perfect for intensive collaboration. It provides an optimal setting for distraction-free focus on the ongoing research. In addition, members of our SQuaRE group came from different places in the world, therefore making it hard to effectively collaborate. Meeting together regularly here in San Jose solved that problem. Since this is our last meeting, it was really interesting to see how progress was made through the years, and new offsprings of the original plans came out of this. Therefore, I strongly support having multiple yearly SQuaRE meetings.

This has been phenomenal. This has greatly influenced my directions and I love working with my SQuaRE mates and am constantly learning from them.

The SQuaRE really functioned well and served an unforeseen purpose: to make researchers of totally different backgrounds to be able to scientifically communicate and to formulate possible theorems. Without the AIM meeting, the language barrier would have prevented the two sides (physics and mathematics) to communicate.

This SQuaRE program is likely to be a turning point in my mathematical career. Not only did it open a new set of research projects but it also allowed me to strengthen the relation with my collaborators. I think this collaboration will be for life.

You have clearly mastered the elements of creating an environment conducive to intense periods of productive collaboration. Our group has made massive progress with our last two AIM visits.

Photo Credit Sonya Kohli of the American Institute of Mathematics.

SQuaRE seminar room discussion.

The opportunity to focus intensively on a single problem for several days and to have the insights of all participants focused together made for a very productive and enjoyable week. For me this SQuaRE has been much more beneficial and productive than other conferences and workshops that I have participated in.

SQuaREs is a remarkable opportunity for us to meet as a group and bring together our individual talents. I assume others have found this to be an "Almost Unique" (if this is an allowable mathematical concept) opportunity within US NSF Institutions.

My experience at AIM was very fruitful and productive. The interaction with the homotopy theorists have helped me greatly in sharpening my ideas on relation of generalized cohomology theories to physics. That also helped me make my proposals much more tangible. I would say that the program at AIM was a turning point in my research.

Other SQuaRE program features

The SQuaRE program provides a valuable resource for members of the mathematical community to collaborate in a unique way especially now, when research funds are scarce. SQuaRE groups work on hard, important, ambitious problems and because the group returns, there is an impetus to keep working throughout the year when not at AIM. Even established researchers who have their own individual grants would find it difficult to bring a group of colleagues together multiple times to work on a project for an intense, uninterrupted period.

Being a part of a SQuaRE project mimics having a mini-three-year individual investigator grant. This opportunity is reflected in the number of excellent proposals to the program and the success is reflected in the number of results and papers produced by the groups.

The SQuaRE program provides a practical way for these small groups to collaborate. One of our recent young SQuaRE participants remarked that while it was difficult for him to spend months away from his home institution at a semester-long program and away from family obligations, it was not difficult to come to AIM for a week each year. There is no administrative work required of any of the participants. The AIM staff take care of invitations, reservations, all logistics, and provide a comfortable research environment for the small groups.

For more information about the program and for a complete list of our past groups and papers, please see aimath.org/pastsquares/.

We hope in the future that this program will continue to flourish and the creation of these tiny communities, which are all part of the larger SQuaRE community, will play an important role in creating mathematical leaders, making the mathematical community more diverse, and advancing mathematical knowledge.

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23

The EPaDel Community

Ximena Catepillán and Linda McGuire

Origins of the EPaDel Section

Since 1978 the seventeenth section of the Mathematical Association of America (MAA) has been called the Eastern Pennsylvania and Delaware Section. This name is usually abbreviated EPaDel, although there is wide disagreement whether to pronounce the first syllable as eep or epp. Beginning with an application for a charter from the MAA, the section was initially called the Philadelphia Section [1] in spite of the fact that its membership ranged throughout eastern and central Pennsylvania, the whole state of Delaware, and southern New Jersey. Even today, 94 years after the founding, the Philadelphia area remains the hub of activity for a geographical region stretching from Wilkes Barre and Mansfield in the north to the tip of Delaware in the south, and from the Shippensburg-Gettysburg-Dickinson triangle in the west to the Lehigh Valley in the east. The formation of the section supplies evidence of a vibrant community of scholars in eastern Pennsylvania, Delaware, and southern New Jersey, one that boasted sufficiently many members to support and sustain its own MAA section.

EPaDel is fortunate that one of its longtime members, the late David Zitarelli, wrote a comprehensive history detailing the early years of the section called *EPaDel, A Semisesquicentennial History, 1926–2000* [2]. This text continues to be an invaluable resource for section members and EPaDel has provided a complimentary copy to every mathematics department in our section.

Given the scope of Zitarelli's work, this chapter will focus on the contemporary history of the EPaDel organization. In particular, we will highlight community-building initiatives and thematic trends that form the core of the section's recent work.

The pillars of the EPaDel Section

The recent history of the EPaDel section reflects a period dedicated to the growth and expansion of our mathematical community. While always aspiring to be a more inclusive organization, EPaDel is invested in its objective to cultivate and sustain community through academic inquiry and personal connection in welcoming, accessible, and collegial spaces. This work may be captured under identifiable and interconnected thematic pillars:

community through inclusion, community through creative engagement, and community through collaborative organizational leadership.

Community through inclusion

The EPaDel section strives to be an inclusive organization by providing a safe and welcoming environment that ensures access, collaborative opportunities, and leadership for people of all backgrounds and identities. The geographic scope of our section spans every sort of institution, from small undergraduate colleges in rural settings to research universities in large urban centers. EPaDel members benefit from this variety, as it contributes to our ability to organically cultivate a membership that includes a broad spectra of race, ethnicity, nationality, socioeconomic status, sex, gender identity, sexual orientation, religious identity, age, health, and ability. Section members often comment that they are comfortable when engaging with the organization and feel free to express themselves in an authentic way.

EPaDel is a better mathematical organization due to this diverse set of perspectives and lived experiences. We see that the human interactions made possible through participation in EPaDel help promote the generation and dissemination of broader ideas. Whether through structured programming or casual social interactions, EPaDel is becoming a site for learning how to reach across difference to foster friendship, collaboration, creative energy, and innovation. We hope that increased efforts in this area will help members become agents to improve their varied academic cultures and, thus, help our institutions attract and retain better talent.

As we know, the mere presence of diversity does not guarantee substantive and meaningful interactions. There are, however, components of EPaDel's structure and traditions that encourage these connections. For example, the one-day nature of our regional meetings makes them available to everyone from undergraduate students to emeritus faculty colleagues. These meetings are low cost for the participant and most are within a two-to-three-hour driving distance from anyone's home institution.

Junior faculty colleagues in the region appreciate the somewhat-regular "New to EPaDel" session where they have the opportunity to present short research talks that give the membership a chance to meet them and find out about their mathematical interests and expertise. These talks have led to young colleagues connecting with potential research partners in the region and receiving invitations to give colloquium presentations at campuses in the EPaDel section and beyond, which is so important for their professional development.

EPaDel also believes strongly in celebrating the contributions of long-serving members of our section. We recently created a formal process to honor colleagues celebrating their 25- and 50-year anniversaries as members of the EPaDel section at our spring regional meeting. During a ceremonial component of the business meeting, the EPaDel Chair publicly recognizes each honoree by providing a brief overview of the individual's professional contributions and achievements. Section members are encouraged to offer their congratulations to these honorees during the remainder of the conference.

Another thread related to inclusivity pointed to by students and faculty alike is best described as informal mentoring. From the graduate student struggling with some aspect of their research to the undergraduate unsure about how to navigate the graduate school

EPaDel Fall Meeting, West Chester University, 2018.

process, from junior faculty seeking advice on how to define their professional lives to more seasoned faculty looking for new academic avenues to pursue, members remark that EPaDel provides a space where they ask their questions and receive useful guidance and suggestions from other members. This "mentoring" happens in informal spaces, often over coffee or lunch, and frequently leads to continued conversations and connection beyond the day of a regional meeting.

EPaDel is committed to building on these strengths and expanding the scope of our efforts to continue to cultivate a vibrant mathematical community.

Community through creative engagement

EPaDel is a site where members can participate in learning activities that support their mathematical development in interesting, relevant, and worthwhile ways. We embrace creativity as part of learning and think of it as a skill to be developed. EPaDel works to support the experience of creative engagement in and with mathematics in a variety of ways.

First, aligning with the overall mission of the MAA, EPaDel promotes conversation and dialogue related to the advancement of mathematics teaching and pedagogy. We consistently offer research-informed sessions dedicated to current thinking, practice, and techniques for teaching mathematics in higher education. These conversations happen as part of presentations offered by keynote speakers, as well as in paper sessions offered by faculty in the EPaDel section.

EPaDel consistently sponsors workshops as part of our regional meeting day that provide important faculty development related to pedagogy. Workshops furnish collaborative spaces to learn new mathematics, explore and experiment with innovative pedagogies, and build relationships by working with colleagues on fun and engaging problems, puzzles, and challenges. These points of connection often help people with similar mathematical interests find each other and, in recent years, have led to scholarly collaborations among section members.

Recent examples of workshops include *The Joy of SET* by Gary Gordon and Elizabeth McMahon (Lafayette College), *Teaching Mathematics with Primary Historical Sources* by Dominic Klyve (Central Washington University) and Nick Scoville (Ursinus College), and *Teaching Calculus Using a Tablet* by Betty Mayfield (Hood College).

These workshops provide an interesting sample of the varied sorts of opportunities EPaDel seeks to offer. For example, *The Joy of SET* session introduced the basic rules associated with the card game *SET* and then used hands-on activities to have participants explore mathematical connections between the game and finite geometry, linear algebra, probability, combinatorics, and coding theory. An added benefit of this workshop was it allowed participants to experience the expert teaching styles of both presenters, including Dr. Gordon, who was the recipient of the section's James P. Crawford Award for Distinguished College or University Teaching that academic year.

The *Teaching Mathematics with Primary Historical Sources* workshop introduced participants to curricular modules known as Primary Source Projects, which are based entirely on primary historical source material. Participants had the opportunity to work in groups on some of these materials, to engage in discussion about the historical modules, and consider practical problems of classroom implementation. The co-facilitators also described opportunities for participants to join their NSF-funded grant effort to expand this initiative.

Participants in the *Teaching Calculus Using a Tablet* workshop learned strategies for how to run a paperless classroom using tablets for reading and interacting with text, giving lectures, note taking, discovery-oriented worksheets, creating mathematical graphics, and submitting homework. Dr. Mayfield demonstrated practical instructional uses of apps such as Notability, Desmos, and Dropbox.

These types of workshops remain a popular component of our regional meetings. They provide ways for section members to expand their teaching repertoires and obtain tangible ideas for immediate classroom use. EPaDel intends to continue to offer similar opportunities in the future.

Second, EPaDel also aims to help members advance and diversify their scholarly research. EPaDel is situated in a part of the country with many active and well-known scholars in pure and applied mathematics. Our regional meetings offer a forum for these scholars, as well as graduate and undergraduate student researchers, to showcase their work and enter into collaborations with other participants. Colleagues are also encouraged to present on ideas and works in progress in order to receive feedback. Participants from various stages of their careers comment on the supportive environment, find encouragement to write up ideas they did not necessarily think rose to the level of publication, and connect with potential collaborators on future projects.

The EPaDel section intentionally reaches out beyond the borders of academia to invite BIG presenters who use mathematics in business, industry, and government. For example, recent keynote speakers at EPaDel regional meetings included Alex Nakahara, Senior Quantitative Analyst for the Philadelphia Phillies (*Analytics in Baseball—It's More Than Just Numbers*) and Kristin Lauter, Principal Researcher and Research Manager for the Cryptography group at Microsoft Research (*How to Keep your Secrets in a Post-Quantum World*).

Mr. Nakahara outlined his work creating analyses and tools for understanding and visualizing data for the Baseball Operations Department. He discussed both quantitative and qualitative skills valued by the Phillies Research and Development Department, as well as some examples of analytical problems his team faces and how they approach them. The story of how he navigated his own unique career path was especially interesting and offered students an important lesson on the value of cultivating intellectual agility and creative thinking when working in industry.

Dr. Lauter described the mathematical problems involved in developing new cryptosystems which can help secure the world's digital infrastructure once a full-scale quantum computer is available. She discussed an upcoming National Institute of Standards and Technology (NIST) competition to standardize new cryptographic schemes for a post-quantum world and offered one possible approach using Ramanujan graphs. Also during her visit to EPaDel, Dr. Lauter served as an ambassador for the Association for Women in Mathematics (AWM) and engaged in many conversations about the benefits of connecting with that organization.

These types of keynote talks are very popular, especially with our student population. Student attendees have the opportunity to engage with speakers during post-presentation Q&A sessions, as well as during coffee and lunch breaks. EPaDel leadership is considering providing specific spaces during meetings for informal conversations with speakers and leveraging the power of social media to facilitate post-meeting follow-up communications.

Third, engaging students in mathematics is at the heart of what EPaDel hopes to accomplish. The student paper session provides a venue for undergraduate or graduate students to present either expository or research-based papers. This opportunity has become so well established that many faculty require presenting at EPaDel as part of senior research capstone experiences for their students.

At each meeting we also offer a student activity where creative structures are used to engage student participants. At recent gatherings the student activities have included solving Martin Gardner's math puzzles, a mathematically-minded scavenger hunt, the workshop *All Tangled Up: An Exploration in Knot Theory*, and team-based problem solving competitions.

Each year, the *EPaDel Student Mathematical Papers Prize* recognizes an outstanding paper written by an undergraduate student at an institution in our section. The winning author(s) are recognized at the MAA EPaDel Section's following Fall meeting, and the student(s) will receive a monetary prize.

From casual conversations during coffee breaks and the closing reception, to more sustained discussions over lunch, members appreciate the unstructured opportunities for connection that EPaDel provides. For example, every meeting has a Silent Auction where participants submit bids throughout the day on books donated to the section. Students and faculty have many fun interactions and impromptu conversations at the Silent Auction tables.

EPaDel is pleased with the growing popularity of its BIG-themed *Careers in Mathematics Conference*. Founded in 1991 by Deborah A. Frantz of Kutztown University, the conference is offered once every other year and is separate from the regional section

Students at a Careers in Mathematics Conference.

meetings. EPaDel institutions volunteer to host the event and expenses are paid through registration fees and the EPaDel budget. Information about the event is also featured prominently in the *EPaDel Newsletter*.

The conference begins with a panel of about fifteen mathematicians, statisticians, economists, software engineers, and others with BIG STEM careers. The panelists speak briefly about their experiences and then answer questions from the attendees. Following the panel discussion, the group splits for the first of three break-out sessions for students. In these smaller sessions, individual panel members give short presentations about their work. During lunch, students enjoy a slide show featuring successful mathematicians from the MAA Press book *101 Careers in Mathematics*. At the end of the conference, a series of mathematically-oriented door prizes are awarded to students.

Attendance has increased significantly in recent years, with students expressing their appreciation for the chance to interact with individuals in careers such as actuarial work, economics, education, finance, statistics, and government. In 2017, 234 students from nineteen different EPaDel institutions attended the conference at Millersville University. EPaDel looks forward to working with other MAA sections to help them establish similar BIG career activities modeled after the *Careers in Mathematics Conference*. The newly implemented Section Officer's *MAA Connect* site will be one of the venues used for this purpose.

The section also appreciates recent steps taken to revitalize and reconfigure the *EPaDel Newsletter*. In the past, the newsletter focused on activities of student chapters in the section. Beginning in 2019, the newsletter broadened its editorial scope to better provide information of interest to all members of EPaDel: faculty, students, and departments. The new editors are dedicated to giving equal emphasis to gathering detailed information on section activities and communicating news to section members. General categories that now appear in the newsletter include Opportunities in the Math Community, Department

News Snippets, stories to inspire other EPaDel-ians, and the Fun Thoughts section, which provides a space for puzzles, interesting facts, jokes, and cartoons. The newsletter is an important vehicle for keeping the community connected between face-to-face meetings. Articles and news items often introduce new ideas for the membership to consider, extend ongoing conversations in the section, and connect the work of the section with the broader efforts and initiatives of the national MAA.

We are consistently inspired by the enthusiasm and creativity our membership brings to these activities. These engagement opportunities help keep EPaDel internally connected and moving forward in a positive manner.

Community through collaborative organizational leadership

EPaDel's leadership includes an Executive Committee which consists of four elected officers, six elected members at large, the representative to the MAA Congress, and several non-voting members. Regardless of the role a member of the leadership team plays, the group has a clear understanding of the goals of the EPaDel section and is committed to attaining them. EPaDel is fortunate to have had strong, collaborative leadership over the last several years. This team laid the foundation for many of the opportunities EPaDel currently offers its membership.

The Executive Committee has a history of open, honest, and respectful communications and has established an environment where people are comfortable engaging in dialogue, discussing options, disagreeing, and taking action. The group's leadership structure is highly participatory, with representation on the Executive Committee from all career stages, types of institutions, and academic foci. Creativity, innovation, and different viewpoints are expected and encouraged.

Photo Credit: Cesar Martínez-Garza, EPaDel.

Recent EPaDel Officers (from left) Ellen Panofsky, Bud Bowman, Ximena Catepillán, Doug Ensley, and Linda McGuire.

This environment allows interested members of our mathematical community to gain exposure to participatory leadership practices. Many Executive Committee members have served in key administrative roles at their home institutions or in national organizations and the entire group learns from their collective experiences. In this way, EPaDel is offering a way for more junior colleagues to gain hands-on leadership experience and learn about leadership opportunities in their futures.

Typically, the Executive Committee has two meetings per academic year, two to three months in advance of a regional meeting. A portion of any such meeting is dedicated to communicating with the on-site organizers for the upcoming meeting to provide assistance with planning and answer questions. The rest of the meeting is spent working on initiatives and planning. Recent projects included revising and updating the section bylaws, discussing ways to better leverage technology and social media to promote the organization, drafting descriptions of the recently-established Early Career Teaching Award, and discussing resource allocation to fully fund the James P. Crawford Teaching Award fund.

One member's view

During my job interview in the spring of 1993, Louise Berard of Wilkes University told me about the vibrant regional MAA section that she called her mathematical home. A few months later I got an email from Louise at my brand new email address at Shippensburg University, located at a different remote corner of that same section—the EPaDel section. Louise asked if I'd like to be the coordinator for the section's visiting lecture program that paired up departments looking for speakers with speakers willing to give talks. Her mentorship and friendship at this time toward me, this new professor at a different college, was centrally important to my professional trajectory … and also tells you a lot about EPaDel culture.

The EPaDel region has over one hundred institutions with mathematics departments, most within an hour of Philadelphia and none more than three hours apart. With this many schools in this tight of a space, the meetings are a real melting pot, with regular attendees from R1s, HBCUs, community colleges, giant publics and tiny privates, and even private high schools, each with a number of students in tow. The EPaDel programming exposes students and their faculty mentors to first-rate mathematics exposition, fully embracing the larger MAA mission, but the meeting attendees themselves are part of the educational experience. When students from Penn, Bryn Mawr, Temple, and Delaware State give talks in the same session, the experience itself shapes their perception of mathematics in a way that no vision statement can.

I got involved in EPaDel because I liked the idea of shaping the mathematics landscape, even if it was only the landscape of my own backyard. I stayed involved because of the people—the people in leadership whose energy is only exceeded by their compassion; the regular attendees who have become good friends over so many shared coffee breaks (and tiny pastries) over so many years; and the students whose inexhaustible excitement and optimism reminds us all of why we are in this profession.

EPaDel is much more compact than most other sections, so with geography on our side our members more easily form viable professional networks outside of the EPaDel meeting itself. Whether for mentoring, organizing student activities, or collaboration

around research or teaching, the bonds formed within the section inevitably lead to an amplification of the section's effect on the mathematical community in our region. I believe EPaDel is the engine that drives community and the support network for those who lead it. —Doug Ensley, Shippensburg University

Challenges

Like most organizations, EPaDel faces its share of challenges. Some arise as a result of changes to the higher education landscape on the national level, while others are specific to the EPaDel section, its membership, and its geographic location.

EPaDel is trying to find innovative and effective ways to promote sustained engagement among our membership between our regional meetings. In addition to materials like the *EPaDel Newsletter*, we are working to expand the organization's presence and members' participation on social media platforms. As the organization navigates what it means to cultivate an online community, this work is in the early stages and the effectiveness of these efforts is not yet clear.

EPaDel regional meetings always occur on Saturdays and, while this works for a large segment of the membership, there are always colleagues who cannot attend because of family commitments, especially related to caring for young children. Some faculty who are pre-tenure express concern that a day spent at the EPaDel meeting is a day they are not working on research or preparing a manuscript for publication. It is concerning that these issues tend to involve junior faculty, the very constituency for which establishing collegial networks through something like EPaDel is so important.

An ongoing challenge is how to effectively address the specific needs of the various constituencies that make up the EPaDel membership. EPaDel tries to be sensitive to the needs of senior faculty and would like to find better ways to engage the most experienced members of our section. Similarly, we need to be mindful of the special circumstances and needs of faculty in the roles of lecturer, visitor, adjunct, and teaching assistant. EPaDel is also considering running specialized break out sessions at our regional meetings for faculty and students at the many two-year community colleges within the section.

Working in higher education in the United States is particularly difficult at this moment in time, with many colleges and universities facing serious issues related to enrollment decline and fiscal viability. EPaDel appreciates that its members' lives are affected by the current climate at their home institutions. Many struggle to attend national MAA meetings as funding to support travel is less available. EPaDel realizes this makes the sort of regional community the section offers all the more important. But, at the same time, this situation puts more pressure on this organization to deliver high-impact, low-cost opportunities for professional growth to an increasingly broad spectrum of faculty and students.

Future plans and concluding remarks

With the MAA only holding one national meeting each year, future work for the EPaDel Executive Committee includes finding ways to effectively expand the work of our organization at the regional level. This national realignment offers an exciting and important opportunity for MAA-EPaDel to provide high quality, regional professional development opportunities.

EPaDel is working on a number of initiatives suggested by the challenges identified earlier. The Executive Committee will take up the issue of whether our currently informal way of providing leadership training to junior members of the Executive Committee should be made more formal, structured, and transparent. The leadership would also like to form a task force, made up of a subset of the Executive Committee and faculty from community colleges in the section, to identify the issues of greatest concern to students and faculty at community colleges, and to consider how EPaDel might be able to better serve this population.

Several ideas are being pursued with regard to reaching out to the more senior members of the section. One possibility is the creation of a regular column featuring profiles of senior faculty in the *EPaDel Newsletter*. To accomplish this, the section is considering having junior faculty volunteer to interview senior faculty, or perhaps have pairs interview each other, as another way of forging connections. Similarly, an idea under consideration is matching senior colleagues who plan to attend the regional meeting with a student partner who would serve as their escort and shadow partner throughout the meeting.

EPaDel would like to have a more comprehensive understanding of its relationship with the national MAA. What does the relationship between these two groups look like and, most importantly, how can it be strengthened and expanded to the mutual benefit of both organizations?

EPaDel is already an inviting and engaged community, but its members always strive to make it better. In consultation with the membership, the Executive Committee is seeking ways to grow the membership and help the organization reach its full potential. In partnership with the national MAA offices and the other MAA regional sections, EPaDel hopes to solidify its place as a site of mathematical community.

Acknowledgments

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Ximena Catepillán recently retired from Millersville University, after chairing the EPaDel Section between 2017 and 2019. Ximena has indigenous roots in South America and is passionate about the mathematics of the pre-Columbian Americas.

Linda McGuire is the Truman Koehler Professor of Mathematics at Muhlenberg College and served two terms as Treasurer of the EPaDel Section. Linda is particularly interested in issues of diversity, equity, and inclusion in STEM, work she embarked on while directing the Teaching and Learning Center at Muhlenberg.

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The Mathematicians of Color Alliance

Michael Young

Where are all the Black mathematicians? Why do so few Black math majors go on to graduate school? And when they do, why do so many of them drop out before they finish? In an era when equity and access are on the minds of many people, these are the kinds of questions that mathematicians need to ask.

In 2016, nearly 1000 mathematical science PhDs were awarded to US citizens. Yet only 29 went to Black mathematicians. In a country where 13.4% of the population is Black, only 3% of math PhDs go to Black people. Clearly there is room for improvement in the profession.

In 2012, only two people of color (both women) were in the Iowa State University mathematics PhD program working on passing the required qualifying exams. Both were struggling and uncertain about how to go about getting help. Their challenges led to the creation of the Mathematicians of Color Alliance (MOCA), an organization at Iowa State University founded to give people of color the community a person needs to succeed in mathematics.

Most of our members are not only the first in their families to pursue an advanced degree, but they are also the first to earn a college degree. Even if their families support their decisions, their parents and other family members often do not know how to help their students navigate the administrative aspects of higher education. Students who don't know the steps involved in earning an advanced degree may feel like they don't belong. Mathematics should be accessible to everyone. We strive to provide support so that the students who are willing to put in the work can enjoy the fruits of their labors.

Since it began, the group has grown and the purpose has shifted to do more than provide support for those trying to gain access to and find success in an advanced degree program. Today, we work toward offering a more complete support system from recruitment through graduation and beyond.

Identifying a need

Shanise, a Georgia native then working on passing her qualifying exams at Iowa State, would become one of the original MOCA members back in August of 2012. She was

still new to the entire system and was trying to figure things out as she went. As a Black student in a state where less than four percent of the population is Black, she already felt a bit isolated. There were many things that she had to get accustomed to, and sometimes she felt like Iowa State was the wrong place for her to continue her education.

Scarlitte, a current MOCA member who grew up in the diverse and agricultural community of Salinas, California, also faced challenges. While her family was incredibly supportive of her choice to pursue a graduate degree in mathematics, they did not entirely understand it. When she was accepted and preparing to leave for Iowa State, she told them how long it would take to get her degree, and to this day, they still ask when she will come home.

Many MOCA members have discussed feeling isolated from their White peers at graduate school, in part because of differing family backgrounds. Many Black students also report feeling that they do not belong in graduate school. For Mike, a MOCA graduate who grew up in South Chicago, there was always a feeling of being an "impostor," as though he couldn't possibly earn a master's degree, let alone a doctorate. When Mike found himself sitting in his first class as a graduate student, he was nearly certain that it was a fluke and that he did not belong because there was no way he was smart enough to be working toward a graduate degree.

For students whose parents and family members don't have experience with higher education, navigating graduate school can seem daunting. This means that students have to look elsewhere for support. For Black students, the lack of Black peers can make it difficult to relate to the people around them. MOCA helps students find a supportive community.

A brief history of MOCA

Iowa State is actively seeking to advance underrepresented students, so we have created a fellowship to help draw in a more diverse group of students from around the country. We do a lot to help set up graduate students for success, including a stipend and tuition assistance. However, there are many other types of support that students need. They need mentorship and guidance to navigate a system that is accustomed to a different kind of student. While Iowa State could help provide the financial assistance to ensure that students could work toward their degrees without the distraction of being in financial peril, MOCA could provide other kinds of support that Black students needed to be successful.

For many people of color coming from the East or West Coasts, Iowa can be quite a culture shock. Though the people in the mathematics department were always incredibly responsive and supportive, dealing with the wider community could be difficult. Mike, the South Chicago native, found the lack of diversity and the kinds of activities available in a more rural area a bit difficult to get accustomed to. And for Scarlitte, though she came from a community primarily based on agriculture, arriving in Iowa came as a shock. In Salinas, different races work together, and she thought that was how most communities functioned. When she moved to Iowa State in the fall of 2016 to work on her graduate degree, she quickly noticed that, instead of the migrants and other people out working the fields, machines managed most of the work in the fields.

In 2012, I approached the director of diversity and chair of the department to request support to create a community for these students. I knew that on their own these stu-

dents would not likely seek others who could understand their background. By starting a community for Black students to come together and talk, I knew that they would start to open up, feel like they belong, and would be able to help each other when they had similar problems. These students faced challenges that no one else would be able to help them with, such as finding a place where women could have their hair done. Mundane tasks that were easy to resolve back home were suddenly more of a problem because the community simply wasn't built with typical Black students' lives in mind.

In 2013, we had three more Black women join the PhD program in mathematics. We discussed the good experiences because it helps reinforce the idea that they do belong and that there are always good things to consider. Of course, we also discussed the problematic aspects, particularly about race.

The four areas of support

MOCA mainly provides four types of support: recruitment, personal, mentoring, and post-graduation. Mentoring in all of these areas helps students feel like they belong at Iowa State.

Recruitment

When I arrived at Iowa State, the initiative to attract underrepresented students had only gained interest from a couple of students. Today, MOCA not only helps recruit Black students to enter the program, but also helps retain them. So far six of our members have either finished or are finishing their PhDs. This success has made it easier to reach out to other Black students around the country and recruit them to the university. As potential graduate students come to check out the program, we invite them to visit with our group for an evening of conversation. They discuss what it is like forming such a small percentage of the population and the unique challenges that they will face, particularly the culture shock.

MOCA has been fortunate in that the people who join the group are incredibly supportive of each other. This is easily seen during the recruitment process. Often, students just need a bit of a push to make that final decision. We want potential students to see the benefits Iowa State has to offer as well as let them know we understand the problems they may face. By visiting with MOCA, prospective students can see that they will have others who understand what it will be like and can offer a protective layer that would otherwise be absent so far from home.

We also provide assistance in understanding the financial aspects of working towards an advanced degree. Many graduate students are new to handling their own finances, and for minority students, discussing personal finances can be viewed as taboo. With many of our members uncertain and uncomfortable about how to obtain necessary financial aid, we know that this is a key component of not only recruiting but also retaining members.

Sometimes what prospective students need is to feel supported while they are preparing for their qualifying exams. There is currently a post-baccalaureate program to help them take a year to fully prepare so that they don't feel rushed through the process. Feeling prepared for the exams increases the likelihood that they will pass, and it proves that they are more than good enough to join the program.

Personal support

Personal support is essential, no matter who the student is. With some students arriving without familial support, the situation can make them feel like they don't belong. MOCA members support each other—if they encounter academic problems, there will be people who can help them through it. Building these relationships as soon as students arrive in the department is important because scheduling meetings becomes more problematic as the semester progresses. Once the friendships have formed, sometimes all it takes is a meeting or two of quietly working side by side to get students to feel like this is where they belong. These relationships now extend beyond graduation as previous members still feel comfortable calling and asking for advice.

Personal support also works as the best way of retaining our students. It is much easier to get discouraged when you feel like you are alone, which increases the odds that a student will drop out of the program. We have been successful in our retention in large part because MOCA members feel they have a strong, reliable group of personal support from people who are like their own personal cheerleaders.

Mentoring

Mentoring is the most enjoyable aspect of working with students. It is also tricky because there are so many components to it. My favorite aspect of mentoring is taking the graduate students to conferences and professional development seminars. These experiences provide encouragement and motivation, particularly when students are struggling because they can see just how much they have to gain by persevering. For those who aren't quite

Photo credit: Michael Dairyko.

Michael Dairyko, Shanise Walker, and Chassidy Bozeman at Iowa State University's 2018 graduation.

sure what direction to go, I help them understand their options and set goals. I always encourage them to set their own personal goals because, in the long run, it always benefits the student to have a gauge that they set and measure themselves by instead of simply accepting what others say about them.

We also rely heavily on peer and group mentoring. A person who has been through the process can provide a more focused approach for those just starting out. While administrators are there to help, many of them do not have the same personal background and have not faced the same kinds of problems. Our mentors fill the gap, helping those just starting out to better manage their time and letting them know that there is someone else who can understand what they're going through.

Post-graduation

MOCA graduates have been a great source of assistance to our current students, and so far they have not required much assistance themselves. Given how in-demand mathematicians are, our graduates quickly learn that they have a lot of options once they finish their advanced degrees. Finding employment does not appear to be a problem—they have been able to find positions that they enjoy within months of finishing their degree programs. By seeing others succeed, more people of color will begin to recognize that earning an advanced degree in math is a real possibility.

A personal look at the effects of MOCA

While the retention of students has been phenomenal, it is the way our students feel about MOCA that really matters.

One of the founding members and first MOCA graduates

Shanise was one of the first Black students from Iowa State to complete a graduate degree in mathematics. Although she came from Georgia, the culture shock was mitigated by the fact that she knew it wasn't a permanent move. Knowing that her time at Iowa State was finite and that she had a strong support group there made it easier for her to buckle down and graduate.

The biggest problem for Shanise was that she did not feel that her research skills were at a level where she could achieve success. MOCA provided her with the encouragement she needed to not only improve her research skills, but also to foster the confidence to keep going. She explained that in the early days she wasn't sure how to budget her time when she was conducting research because there were so many other things that needed to be done. Learning how to carve out time to conduct meaningful research was difficult, but it has been a skill that she has mastered. Now she is able to put those skills to work in an entirely different environment.

It took her six years to earn her degree, and she remembers the time at Iowa State with a lot of fondness and humor. Looking back, that first year was the hardest because it was so difficult to connect to other students. After the founding of MOCA, things became a lot easier. Today, she occasionally takes calls from students looking for a little insight into the program or who need some advice on things to do in the area. She found a fantastic job at the University of Wisconsin–Eau Claire, about ninety minutes away from Minneapolis, a

turn of events she never would have imagined in those early days. When she travels, she actively encourages prospective students to consider Iowa State.

A successful graduate

Mike initially had no intention of going for an advanced degree in mathematics because he didn't think that he was smart enough to do it. Having earned his undergraduate degree at Pomona College in Claremont, California, Mike was ready to start looking for a suitable position. Then he met Michael. Michael convinced Mike to just check things out and see if there was a school where he would be interested in working on a graduate degree. Mike visited two different schools, but after he visited Iowa State, he knew that was where he wanted to go if he was going to pursue another degree.

One of Mike's biggest problems was his self-described Impostor Syndrome. He just never felt like he belonged. Then he talked to the other members of MOCA, and found that two of them felt exactly the same way. Other students began to say that they felt that way too, but that it was a matter of ignoring that doubt and working through those first few weeks to see that they were there because they had earned it.

Some of his fondest memories are of the meetings and potluck meals the group had. While the study sessions were fantastic, it was nice to have the socialization of the meals to really help them talk about things. They could discuss their problems and experiences. Their conversations validated some of the things he felt and helped him be more open. He was an active member of the water polo team during his time at Iowa State, so he felt like he constantly had people cheering him on in many different areas of his life.

Today, he works with the Milwaukee Brewers, a position that he accepted less than two months after earning his doctorate. His time at Iowa State taught him that he is not only good enough and smart enough, but also that he can dream in ways that go much further than he had originally imagined.

The unique experience for a current member

Scarlitte first had a taste of what it would be like to go to Iowa State in 2015 when she attended the Research Experience for Undergraduates (REU) program. She knew that the people in the mathematics department were welcoming, and that she would stand out a bit as Mexican, but this did not seem like a reason to ignore the great experience she had during her REU. It just meant doing a bit of adjusting to the entirely different community dynamic.

When Scarlitte joined MOCA, that made her experience that much more enjoyable. One of the things that she has found to be most beneficial is having the chance to see other people of color in the field. She has been able to attend conferences and lectures where people of color have served as primary speakers, reinforcing the idea that she is in the right place—that she belongs. She wishes MOCA had more regularly scheduled meetings. However, that is always a delicate balancing act because each graduate student has his or her own unique research and schedules that make this a challenging task. Still, she loves spending time with other MOCA members because she loves to see how others in similar positions are doing and know that she is not alone.

Concluding thoughts

Trying to go at it alone in the field of mathematics is like trying to learn a language without ever speaking to another person in that language. Everything is more challenging. Yet this is the situation that most minorities face, not only when they work towards their bachelor's degree, but also when they strive for a master's degree or a PhD. I think that what makes it all the more difficult is that students may not even realize that it is a problem because they have been desensitized to it. Being a part of a community creates a feeling of belonging. However, it is unreasonable for us to expect graduate students to create this collective when they arrive on campus to study mathematics. The onus is on us, mathematics faculty, directors, program coordinators, and leadership, to do what is required to give each student the opportunity to be successful.

Michael Young earned his PhD at Carnegie Mellon University. He is now Associate Professor in the Department of Mathematics at Iowa State University where he serves as the Diversity Director.

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The Story of RUME
Forging a Community of Practice

Stacy Brown and Annie Selden

The MAA Special Interest Group for Research in Undergraduate Mathematics Education began as a community of practice. This idea, introduced by the social learning theorist, Etienne Wenger [1], describes communities that come together around a joint enterprise and work not only to develop the practices and ideas that draw them together but also to negotiate "a shared repertoire of communal resources (routines, sensibilities, artifacts, vocabulary, styles)." This apt description of the development of RUME provides a thematic exploration of the ways members worked to grow a professional community.

Early years

A community of practice begins with a few individuals who share interests and even knowledge but lack the benefits of established community practices, terminology, language, artifacts, and resources. Critically, the individuals need to find each other and to discover their common interests. The first steps towards creating RUME occurred in the late 1980s when a group of individuals, primarily Ed Dubinsky, Alan Schoenfeld, Jim Kaput, Tom Dick, Greg Foley, Warren Page, and John Selden, recognized their shared interests in research in undergraduate mathematics education and took the necessary steps to form CRUME, the Committee for Research in Undergraduate Mathematics Education, a joint committee of the AMS, MAA, NCTM, and AMATYC.[1] As members of this committee, these individuals began to organize opportunities for other interested individuals to learn about, participate in, develop, collaborate on, and disseminate research in undergraduate mathematics education (RUME).

In 1991, CRUME organized special sessions at the Joint Mathematics Meetings (JMM) of the AMS and MAA designed not only to share their research but also to invite and encourage those new to the idea of research in undergraduate math education to join their sessions and discussions. All were welcome, regardless of level of expertise.

[1] AMS (American Mathematical Society), MAA (Mathematical Association of America), NCTM (National Council of Teachers of Mathematics), and AMATYC (American Mathematical Association of Two-Year Colleges).

Working to develop resources for the community, Ed Dubinsky, Alan Schoenfeld, and Jim Kaput began editing a series of volumes, *Research in Collegiate Mathematics Education* (*RCME*) in 1994. These volumes were part of the College Board of the Mathematical Sciences' "Issues in Mathematics Education" series. Members of CRUME also worked with *Mathematical Reviews* to obtain the subject classification 97 Mathematics Education. The creation of a category for the discipline was important for it meant that mathematics education could be reviewed by *Mathematical Reviews*, and it served as a step towards legitimizing mathematics education research in the eyes of mathematicians. By working to provide professional opportunities where interested individuals could come together, learn about, and begin to disseminate their work, these early members created the necessary conditions for what Wenger calls the "coalescing" of a community.

As interest in RUME continued to grow, so did attendance at the JMM special sessions and the *RCME* series readership. This led Ed Dubinsky to seek funding from the Exxon Educational Foundation for a series of conferences on RUME. These conferences were held, in addition to the JMM special sessions, in September 1996, 1997, and 1998 with the first two in Mt. Pleasant, Michigan and the third in South Bend, Indiana and led to some offshoot conferences in other areas of the country. Like the JMM sessions, these were open-door conferences, where all who were actively interested in RUME or who sought to learn about RUME were welcomed. They were places for discussion, collaboration, and exploration. Those who came established connections with others who either carried out RUME research or wished to learn about it in order to implement RUME findings in their college classrooms. A community soon coalesced and, not surprisingly, so did interest in becoming a professional organization.

In 1998 members of CRUME began working with MAA leadership to form the first special interest group of the MAA (i.e., SIGMAA). This work required not only more than eighteen months of bylaw drafting, work primarily done by Annie Selden and Ed Dubinsky, but also meetings of the CRUME membership. These collective efforts culminated in January 2000, when the MAA established the SIGMAA on RUME, whose purpose was: (1) to "foster basic research in undergraduate mathematics education (RUME) and its application to improving teaching practice" and (2) to "provide organizational support for the conduct of RUME and its dissemination through talks, conferences and publications."

Growing the SIGMAA on RUME

A community of practice comes together for the purpose of shared interests and learning; then, according to Wenger [1], they strive to develop shared meanings through participation in the community and developing a written record of their work.

Shortly after the SIGMAA on RUME was established, members began to regularly hold Annual Research Conferences outside of the Joint Mathematics Meetings's contributed paper sessions.[2] These conferences offered an opportunity for members to submit papers and participate in a community by discussing research, engaging in critique, and otherwise collectively growing their discipline. They also provided a place where those who were interested in learning about RUME or hoping to begin a research program in RUME could

[2] See sigmaa.maa.org/rume/Site/Conferences.html for a complete list of conferences.

join the community. As attendance at the contributed paper sessions at the JMM meetings and at the annual conferences increased and the discipline of RUME began to coalesce, so did an awareness of the need for a way to publish their research.

For the SIGMAA on RUME, publishing was difficult. In RUME scholarship, the mathematics itself is examined and seen as highly relevant, whether that be the learning of calculus, linear algebra, real analysis, abstract algebra, or other advanced topics. In other words, RUME researchers do not study pedagogies or curricula irrespective of content. Consequently, until recently, there were few outlets to publish this type of research. In particular, the research of members of the SIGMAA on RUME was outside the aim and scope of mathematics journals and ill-suited for publication in educational journals geared towards researchers and practitioners who focus their work on grades K–12.

Beginning in 2002, conference programs included the abstracts of the research papers presented at the Annual Conference on Research on Undergraduate Mathematics Education. In 2006, RUME began producing *RUME Conference Proceedings* for the annual research conferences. With these, the community created its own artifacts. These *Proceedings* initially took the form of an electronically-linked program available on the SIGMAA on RUME's website and this format was maintained until 2011.

In 2011, a full referee process was established for the *Conference Proceedings*. The referee reports offered valuable feedback to authors and fostered discussions regarding the criteria which would be employed to evaluate the community's professional work. In particular, efforts to agree on criteria for evaluation provided an additional avenue for members of the community to: (1) negotiate and develop shared practices and meanings; and (2) discuss current practices regarding the forms of feedback and support that could be available to those who were both established or new to the field.

Establishing a professional academic identity

As the SIGMAA on RUME grew and established its identity, members began to recognize and address the ways this emerging community lacked the hallmarks of an academic discipline; namely, accolades and discipline-specific journals.

Annie and John Selden initiated efforts to develop professional accolades. These efforts culminated in November of 2004 when the MAA Board of Governors approved the MAA's Annie and John Selden Prize for Research in Undergraduate Mathematics Education. This award honors a researcher who has established a significant record of publication and who has been in the field for at most ten years. With the introduction of the Selden Prize, members of the RUME community had their first opportunity to recognize significant contributions to the growth of their discipline.

In line with the Seldens' efforts to establish professional accolades, the 2006 SIGMAA on RUME leadership not only established the *Conference Proceedings* but also instituted conference paper awards. These awards, a Best Paper Award and an Honorable Mention Award, were presented from 2006 to 2019, and were awarded to authors of papers that made substantial contributions to the field in terms of pioneering new areas of inquiry or providing critical insights into existing research programs.

Furthering the process of recognizing members' contributions to the community, the SIGMAA on RUME Mentoring and Service Award was established in 2017. The inaugu-

ral recipients of the award were Annie and John Selden, for their extensive service to and mentoring of members of the RUME community.

Accolades, however, were not enough. For an academic discipline to emerge, artifacts of practice are needed that are recognized by members' home academic institutions and by other academic disciplines. For the SIGMAA on RUME, this meant avenues for the publication of research beyond the edited and refereed conference proceedings. In other words, the community needed a discipline-specific journal.

Work to establish a journal focused on RUME scholarship began in earnest in 2008. Karen Marrongelle and Chris Rasmussen worked first as members of the RUME leadership and then independently for a number of years, meeting with the MAA and AMS, writing grants to the NSF, and eventually working with Michael Thomas of the University of Auckland in New Zealand and Springer publications, to establish *IJRUME*, the *International Journal of Research in Undergraduate Mathematics Education* in 2015.

The existence of avenues for publication and professional accolades further established the community's professional identity and, consequently, a sense of credibility among its members. In particular, these critical efforts provided an impetus for members to describe the values of their community, to articulate practices of evaluation and critique, and to develop the language of the field. These conversations took place at many levels and in many places. The community valued the insights of all participants and viewed our different backgrounds and institutional settings as strengths.

Beyond "All are Welcome"

> *I attended my first RUME conference in 1997. Even then, I was delighted and surprised that people were interested in what I had to say—the small community made me feel welcome. Our community has grown, and I think the ways we try to nurture and support one another has grown even more. I very much appreciate the various ways in which our SIGMAA RUME community welcomes new people with new ideas. Because of this community, I have grown as a mathematics education researcher.*
>
> —Hortensia Soto

During the formation of the SIGMAA on RUME and members' efforts to further develop RUME as an academic discipline, members also sought to create a community in which "All are welcome"—where a shared interest in RUME and a commitment to participate and learn formed the basis for joining the group.

At the first RUME conferences, the pioneers of RUME gathered to share current research findings and intentionally created a place of learning. Members actively invited those interested in RUME, regardless of level of expertise. Graduate students and junior faculty were welcome and came with the expectation that the groups would productively critique their ideas with the aim of advancing and supporting their work. Through these interactions, participants began to feel as though they were part of a joint endeavor.

As the community grew along with the discipline, new areas of research developed. In an effort to support these newly emerging subfields, the SIGMAA on RUME developed opportunities for members of these subfields to come together during "working group" sessions, which occurred prior to the annual research conference. The development of

Photo Credit: Hortensia Soto.

Megan Wawro, Vilma Mesa, Shiv Karunakaran, Hortensia Soto, and Paul Dawkins, members of the 2020 RUME Executive Committee.

working groups meant that individuals could gather with others working on similar problems and could receive both support and feedback for emerging or on-going work, collectively define research programs, find collaborators, and discuss connections to other subfields.

Recognizing the need to support women in RUME, members of the SIGMAA, including Jess Ellis Hagman, Megan Wawro, and Hortensia Soto, independently sought National Science Foundation funding to hold annual conferences focused on the development of women in RUME. These one-day Mentoring and Partnerships for Women in RUME (MPWR) conferences were initiated in 2013. The MPWR meetings have played, and continue to play, an important role by offering opportunities for women at all career stages to develop professional relationships and find a sense of belonging.

Between 2012 and 2015, members formed a working group focused on research on equity in mathematics education. This attention led to the creation of the RUME Committee on Equity and Mentoring. Over a two-year process this group surveyed the membership to understand the perspectives, issues, and concerns of the community, drafted statements, and responded to extensive feedback. These statements were approved in 2018 and explicitly articulated the SIGMAA on RUME's commitments to equity in undergraduate mathematics education at all levels of the discipline.

Mentoring and collaboration

The Executive Committee and the Program Committees of the SIGMAA on RUME have worked to provide more informal ways of ensuring that members and participants feel welcome and that they belong. They have always strived for informal conference environments with the price for many shared meals included in the conference registration fee. Conference lunch tables are designed so that more-junior participants can meet with a more-senior colleague in the field to converse informally about things such as navigating graduate school, applying for academic jobs, structuring a journal paper, balancing work and family life, and so forth.

Program Committee members have made a point of attending the conference presentations of new participants and offering helpful feedback. They have also provided stickers for members of the Local Organizing Committee on name tags so participants could identify the best colleagues for questions about the conference organization and local area. The Program Committee has reserved tables at local restaurants for dinner-on-your-own evenings and provided sign-up sheets so participants could easily eat together. They arranged morning runs and events including game nights, especially at out-of-the-way conference venues, so participants could spend an informal evening together.

For a brief period of time, with the help of Exxon Educational Foundation funds, the SIGMAA on RUME organization was able to provide mentoring mini-grants. These mini-grants offered an opportunity for graduate students or junior faculty to travel and work with more senior faculty on research projects in undergraduate mathematics education. In addition to these formal opportunities there have also been many informal collaborations that grew out of these interactions to help create a sense of belonging.

Concluding remarks

The SIGMAA on RUME developed as a community of practice: shared interests and goals enabled researchers who differed in training and location to come together around a joint enterprise and work not only to develop but also negotiate a shared repertoire of communal resources and practices. Members of this community worked hard to develop the hallmarks of a legitimate academic discipline, including the creation of a refereed professional journal and the acknowledgment of outstanding work. These efforts led the community to reconsider the practices of our emerging discipline, our values, and our commitments. This chapter is not a telling of the SIGMAA on RUME's history but rather an exploration of the ways its members worked to grow a professional community. Critical to this development was an expectation that those present would welcome and support new members, so as to foster growth in our community. The development of the SIGMAA on RUME was and continues to be a human endeavor focused on research in undergraduate mathematics education.

Reference

[1] Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems Thinker*. 9(5): 1–5.

Stacy Brown served on the SIGMAA on RUME executive committee from 2015–2018 and 2009–2012. She is an associate professor at the California State Polytechnic University, Pomona and currently serves on the Editorial Board of *IJRUME* (*International Journal of Research in Undergraduate Mathematics Education*).

Annie Selden was instrumental in establishing the SIGMAA on RUME and served as its second Coordinator. She is Professor Emerita of Mathematics from Tennessee Technological University and currently serves on the Editorial Boards of *IJRUME* (I*nternational Journal of Research in Undergraduate Mathematics Education*) and *ESM* (*Educational Studies in Mathematics*).

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MSRI Addresses the Challenge

Hélène Barcelo and Michael F. Singer

The Mathematical Sciences Research Institute: Purpose and Goals

Founded in 1981, the Mathematical Sciences Research Institute (MSRI) aims to further mathematical research through broadly-based programs in the mathematical sciences and closely related activities. MSRI realizes this goal by hosting researchers in semester- and year-long programs in key and timely areas of research in the mathematical sciences, training the next generation of researchers, reaching out to ensure equitable representation of historically underrepresented populations in its mathematical activities, and communicating the power and beauty of mathematics within the profession and to the general public.

MSRI typically hosts two major programs at a time, each lasting a semester or a year. Those programs, designed to support and enhance communities of researchers and catalyze their collaborations, represent the core of our mission. Long-term visitors come for periods ranging from one month to ten months. During a semester-long program, MSRI becomes a world center of activity in the field of the program, with visits from top experts as well as from those who will become the next leaders. Welcoming about 1700 visitors a year, MSRI also sponsors or hosts workshops on diverse mathematical and educational issues; summer programs for undergraduate students, graduate students, and faculty; and diverse public events both at MSRI and elsewhere in the world.

An awakening

In the mid 1990s, Bill Thurston and Lenore Blum, then Director and Deputy Director of MSRI, were concerned about the lack of diversity in the Institute's programs. They created the Human Resource Advisory Committee (HRAC) in response. The HRAC was mandated to advise MSRI on how to be inclusive, diverse, and equitable. Over the years the committee proposed several new activities meant to encourage researchers from a variety of backgrounds to learn about a new field as well as to provide ample opportunities for people to network and form lasting collaborations.

When the first author of this chapter came to MSRI in 2008, she was certainly aware of inequities, implicit and explicit bias, and even outright discrimination in academia and in mathematics. She worked to ensure that MSRI would be diverse and inclusive and that MSRI would provide a collegial environment to all. In the words of Silvia Bozeman (former HRAC member and later co-chair), MSRI would be "a home away from home." With increased efforts to reach out to members of groups underrepresented in mathematics, Hélène felt that MSRI was doing as well as it possibly could. There was a pipeline problem and that was certainly not for MSRI to solve, she thought. After all we were "simply" a research institute with goals to promote research. The pipeline issue was the domain of the universities. Then it dawned on us that graduate program chairs of math departments had a similar way of thinking: *Despite our best efforts at reaching out to underrepresented groups, we cannot improve their representation in our departments. We have done everything we can. It is a problem for the undergraduate chairs.* This process continues from one level to the next and soon we realize that it is a problem of society—certainly we cannot be expected to solve it. This line of thinking may be rational, but it leaves the problem unsolved.

Realizing that it was—and is—MSRI's problem was an important step in our approach to improving the representation of women and minority groups. Facilitating development, cooperation, progress, and inclusiveness for those with different backgrounds, at different stages of their careers, and from many different institutions requires multifaceted efforts. In addition, it is important to recognize that for some populations inequities exist and need to be redressed. For some a remedy is to increase the visibility and impact of their research, for others it is to increase their productivity by catalyzing collaborations. At MSRI everyone from the building manager to the trustees has become invested in making a difference. Governing committees are dedicated to ensuring that diversity, inclusivity, and equity are an integral part of *all* activities. Special programs have been established to bring to the institute people who have been historically underrepresented or marginalized. Targeted networking workshops were created to provide a sense of community. Carefully designed outreach programs were established to welcome everyone into our mathematical community.

By approaching the problem from as many angles as possible, MSRI has significantly increased the participation of historically underrepresented groups in its activities. This chapter focuses on some of the measures MSRI has taken to make inclusivity, diversity, and equity an integral part of the institution. In turn, these initiatives support and enhance communities of researchers at MSRI.

MSRI's semester programs and workshops

To meet our goals in the semester programs and workshops, MSRI implements various activities from the planning stages through the exit surveys.

At the planning stage

Planning for a program begins at least two years in advance and proposals (both solicited and unsolicited) are reviewed by MSRI's Scientific Advisory Committee (SAC), and its Human Resources Advisory Committee. The SAC is a rotating committee that selects and plans the Institute's programs and works with the organizers of these programs on selec-

tion of key participants. The HRAC augments the SAC's care for human resource issues. HRAC's ten members help recruit participants from underrepresented groups and develop new MSRI activities to promote the involvement of these groups in the mathematical sciences. For example, at the very beginning of the process, proposal teams must designate an Organizing Committee which is representative of the mathematical community, including at least two women. In our experience, when female mathematicians serve on an Organizing Committee, it generates a more diverse list of applicants and participants. This outcome is consistent with yearly statistics compiled by the AMS which found a strong correlation between having women organizers and the number of women speakers in AMS special sessions (see, e.g., "Statistics on Women Mathematicians," Notices of the AMS, October 2018, 2019, and 2020). In addition, MSRI's Human Resources Advisory Committee is involved in all the activities of MSRI and guidelines require that organizers of activities must respond seriously to its recommendations. HRAC also advises on the selection of special programs aimed at underrepresented groups and aids MSRI in the evaluation of its programs and diversity efforts.

During the program

When researchers are invited to MSRI, they are given information concerning visitors and family services. MSRI's Family Services Consultant assists mathematicians in finding schools and childcare in Berkeley. Between Fall 2014 and Spring 2020, this consultant assisted 192 members with securing childcare services and school enrollment for over 240 children. The generous support of private funders allows the Institute to offer family support to women participants in our programs and workshops who have children ages 14 and under. The funds are intended to offset the cost of childcare to enable mothers to focus more easily on research during their stay at MSRI. Recipients may use these grants for childcare expenses from local resources in Berkeley, or for any other form of childcare (such as hiring a nanny at home, bringing a caregiver with them to Berkeley, etc.) in order to give recipients the freedom to use these funds in a way that is most useful to their family. Both of these programs are particularly helpful to women hoping to participate in a program, since the burden of caring for young families still falls disproportionately on women.

> *I am incredibly grateful for the financial family support I have received during my stay at MSRI. It allowed my family to acquire the after-school care we needed, allowing my husband and myself to work knowing our daughters were well cared for. Additionally, without the worry of the added financial burden of childcare, I found it easier to focus on my work, attend workshops and talks, and participate more fully during the GTC program. The family support offered by MSRI made my stay here that much more enjoyable and productive. Thank you!*
>
> —2017 participant, Geometric and Topological Combinatorics

Childcare support is important not only for the parent, but also to all participants of the program as well, as this comment from a male postdoc about his mentor suggests:

> *At the Fall 2018 MSRI program on Hamiltonian Systems I was introduced to [..]. While I was familiar with her work, I had not yet met her at any recent conferences.*

We started collaborating on an exciting new project early in the semester and she served as an unofficial postdoctoral mentor for me, offering feedback on my talks and other career advice. After the MSRI program I started a new postdoc, close to [..]'s home institution. In addition to our continuing collaboration, she has helped introduce me to mathematicians in this area. Caring for a young child limits one's ability to travel, and had [..] not been able to attend the MSRI program, my experience in Berkeley would have been greatly diminished. —2018 male participant, Hamiltonian Systems

Once a program begins, MSRI becomes a hub of mathematical activities. Among the special features of the programs are the Connections and Introductory Workshops and the Postdoc Program.

Connections Workshop and Introductory Workshop A program begins with a Connections Workshop (CW, formerly Connections for Women) and an Introductory Workshop (IW). The CW facilitates social networking in a mathematical context where mathematicians who identify as women are a majority and includes both a discussion session on career development and a dinner for the participants. As is the case for all MSRI workshops, registration to attend Connections Workshop lectures is open to all interested researchers regardless of gender. What makes this workshop stand out from others is that the speakers are mainly women. Some participant comments attest to its impact:

I appreciated the diversity of the group of participants: mostly female and from many different backgrounds. Scheduling the Connections for Women workshop right before the Introductory Workshop is very effective, since then during the Introductory Workshop women have already formed some connections with other participants, and are already familiar with the Institute. Personally, the Connections for Women workshop has led to a potential new collaboration for me with one of the speakers.
—2017 Participant, Harmonic Analysis

This is my first workshop that has a gender perspective to it, and I loved it. Not only was it great not being the only woman in the room, but also the panel discussion motivated some great discussions and gave some really good points.
—2019 Participant, Derived Algebraic Geometry, Birational Geometry and Moduli Spaces

The panel session was really stimulating (to me as a "senior" male who has done lots of training in unconscious bias etc but who still learned a lot …).
—2017 Participant, Harmonic Analysis

The IW immediately follows the CW and is meant to set the stage and provide the context for the program. The intended audience includes members in the other programs, members of the local mathematical community, and participants from outside the area selected especially for the workshop, particularly women, minorities, mathematicians not located at research centers, and graduate students. In selecting participants, priority is given to these latter groups. One of the objectives is to help mathematicians break into a new area of research. These introductory workshops have been effective in broadcasting the goals, ideas, and techniques of a particular field to the mathematical public at large, as well as in bringing the MSRI community together as a whole.

Introductory Workshop of the Microlocal Analysis Program, Fall 2019.

Postdocs A program typically includes postdocs. MSRI strongly believes that both formal and informal mentoring are important roles for established members of the program. Thus MSRI emphasizes this responsibility throughout the preparation and implementation of the program. The mentor and the postdoc are expected to designate a weekly meeting, including a discussion at the beginning of the semester about the project(s) the postdoc will pursue. The mentor is expected to introduce the mentee to senior members in the postdoc's area, give advice and feedback concerning the writing of papers and grant proposals, presenting talks, the ins and outs of publishing, and various other professional issues that arise in the course of their career. Early in the semester, the Directorate has several lunches with small groups of Postdocs to learn about each of them and make sure that their mentoring relationship and involvement in the program are going smoothly. This one-on-one mentoring is meant to provide a safe and stimulating environment for all postdocs.

After the program

Before leaving MSRI, all members complete an exit survey that provides feedback on their experience. MSRI also writes to a selection of members who have attended programs two, four, and six years earlier. The following comments capture some of the long-term impacts:

> *Another long-term impact is the collaboration between researchers in commutative algebra and in cluster algebra, which was the topic of the sister-program that Fall.… The human resource story is also impressive. Our post-docs were quite diverse and began many successful collaborations and made contacts that eventually led to strong careers. All but one of them is now in a long-term position at a university!*
>
> —Organizers, 2012–13 Commutative Algebra Program

I participated while being a postdoc in Germany and was able to make several lasting connections during the stay at MSRI, some of which are leading/have led to very fruitful collaborations. Also, I made lasting contact with several leading figures in the field whom I now feel more inclined to ask research and career help questions.… The younger generation of our community/field is well-networked due to the program and this led to many collaborations and also contacts, where we ask each other questions slightly out of our own respective area.

—Research Member, 2013–14 Mathematical General Relativity Program

Reaching out and bringing in: other activities to broaden participation

Other activities to redress inequities and promote inclusivity reach beyond our programs. These include the following:

Summer Research in Mathematics (SRIM) Existing women's mathematics conferences are valuable collaborative opportunities, but they are also very short in duration, typically lasting only a week, meaning projects remain unfinished once the participants return to their usual professional and personal responsibilities. MSRI's Summer Research in Mathematics program provides space, funding, and the opportunity for in-person collaboration to small groups of mathematicians, especially women and gender-expansive individuals whose ongoing research may have been disproportionately affected by various obstacles including family obligations, professional isolation, or access to funding. Researchers work on a project for two-to-three weeks at MSRI during the summer. Through this effort, MSRI aims to mitigate the obstacles faced by these groups, improve the odds of research project completion, and deepen their research experience. Private sources of funding for family support make it possible for women with children to fully participate in its scientific activities. Thanks to grants from the National Security Agency, the Lyda Hill and the McGovern Foundations and Microsoft Research, full support is provided including lodging, food, and travel. Beginning in 2017 with four groups for a total of sixteen women, this program increased to six groups totaling twenty women in 2018, to thirteen groups totaling forty-six women in 2019, and to eighteen groups totaling 81 women and one man in 2020. A total of 29 papers have been published, accepted, or submitted from these four summers. The Summer Research in Mathematics program is extremely popular and has a very competitive application process (in 2019 there were 153 applicants, and in 2020 there were 294).

We also visited quite a bit with others at MSRI. In particular, some of these lunch/tea time chats resulted in invitations to speak at another participant's home university. This also led to a lot of discussions about what we can do to promote both our own careers and those of women in mathematics in general. Bringing collaborators together is so important. There is so much more progress we can make on our joint projects when we can work through ideas in person. Further, it is likely that neither of us could have arranged such a meeting if this program didn't also cover travel and other arrangements for our children. In a female-only collaboration I think we both stop censoring ourselves so much. We throw out crazy, naive ideas that turn out to work, or to lead us to something else interesting, or to just fall flat. In any case, we ask and answer the

"dumb" questions, instead of assuming that the answers are obvious to everyone else. Often, they're not obvious, and lead to really nice results. —2019 participant

Our week at MSRI enabled us to develop a small project into something substantial. We are working slowly for exactly the same reasons that [the time at MSRI] helped us: we are overflowing with commitments at home (eight children across three authors!), and the isolation permitted the focus needed to advance. —2017 participant

The African Diaspora Joint Mathematics Workshop (ADJOINT) ADJOINT is designed for US researchers with PhDs in the mathematical and statistical sciences, especially those from the African-American mathematical community, who are interested in conducting research in a collegial environment. Beginning with a two-week summer workshop at MSRI, small groups of mathematicians work with research leaders on various research projects. The ADJOINT program continues throughout the year by providing support for periodic virtual meetings as well as travel funds to enable visits among collaborators. MSRI also provides additional support for participants to present results at national and international conferences and publish in peer-reviewed journals. The 2019 ADJOINT pilot workshop consisted of twelve mathematicians who participated in one of three research groups. A respected African American mathematician with a well-established research program led each group. S. J. Gates led a group of three mathematicians on "The Study of Mathematical Adrinka Symbols: From Physics to Mathematics Investigations Across Algebraic Topology and Graph Theory." Group member Kevin Iga of Pepperdine plans to publish a book to make the development of this young topic accessible to the mathematical community. Michael Young worked with a group of four researchers on tournament problems and Edray Goins, together with five other mathematicians, studied compositions of Belyi maps and their monodromy groups. Both of the latter groups are working on publications. All teams were predominantly comprised of African-American mathematicians at various stages in their careers.

It was great working with other African Americans. However, for me the best part about the program is that more African Americans will be writing papers together and presenting to the math community. [ADJOINT] can make a direct impact on the number of research papers authored and conference presentations given by African Americans. That is a huge positive.

… I think this program is an absolute triumph in and of itself. The real work might be in determining, via longevity of the program, sufficient tweaks in order to foster enough interaction with groups who participate, and early career African-American mathematicians so as to create space and a bit of momentum for bona fide mathematical collaboration to develop.

Summer Graduate Schools Each summer, MSRI organizes and runs several Summer Graduate Schools on topics of exciting current research. In recent years MSRI organized between ten and twelve schools each summer. At these two-week events, forty to sixty students meet with their peers and future colleagues from all over the world, in an environment of intense collaborative work. MSRI widens the pipeline of talented mathematicians by actively encouraging summer school applications from members of groups

currently underrepresented in mathematics. Recently, 85% of the participating students are US-based and from all regions in the country. Graduate students can be nominated from all institutions, but each of MSRI's 110 Academic Sponsor institutions are allowed to send two students to MSRI's Summer Graduate Schools; or three students if at least one is a woman or minority; or four if the group includes both a woman and a minority. This last option went into effect in 2016 and has resulted in a substantial increase in the number of women and minorities sent by sponsors. In 2015 there were 28% women and 11% from other underrepresented groups while in 2018 the percentages were 30% and 19%. These comments from three attendees at the 2018 ∂-Problem in the Twenty-First Century Graduate Summer School highlight the success of the program:

> *The material was really great, but perhaps even better was the chance to meet and work with others in my field. Though I am surrounded by other grad students in Math or even Analysis in my department, it's much harder to find colleagues in my field. Working with others who have similar backgrounds to my own and are interested in similar questions was an amazing experience. I learned more in the two weeks of working with these new friends and colleagues than I had learned in months of working on my own.*

> *The best part about the summer school was interacting with the other people at MSRI outside of the lecture hall. In fact, I am now collaborating with another student on an idea we had one afternoon while chatting in the common area and there may very well be a paper in the works.*

> *I think no word can be used to express the joy, the surprise, and satisfaction I have revived here. It is something that not only encourages me very much, but also makes me appreciate what math really is. The subject might be seen as difficult, but the fun is uncountably infinite!*

MSRI's Undergraduate Program (MSRI-UP) MSRI-UP aims to increase the number of graduate degrees in the mathematical sciences, especially doctorates, earned by US citizens and permanent residents, by cultivating previously untapped mathematical talent within the US Black, Hispanic/Latinx, and Native American communities. Each summer eighteen college students participate in a mathematics research program under the direction of faculty and graduate student mentors. They complete a research project in collaboration with other MSRI-UP students. They also attend workshops aimed at developing skills and techniques needed for research careers in the mathematical sciences. They learn techniques that will maximize a student's likelihood of admission to a graduate program as well as the likelihood of being awarded a fellowship. After a rigorous summer research experience, MSRI-UP participants encounter a long-term support structure that offers mentorship for the rest of their careers. The program's effectiveness is demonstrated by the fact that since its inception thirteen years ago, 223 students have participated in MSRI-UP. Of these, 164 went to graduate school and, so far, 70 have received master's degrees and 37 have received PhDs in the mathematical sciences. A further strength of the program is its successful focus on cultivating the underutilized mathematical talent within the Black, Hispanic/Latinx, Native American, and Pacific Islander populations, which constitute 89% of MSRI-UP alumni.

This has been, by far, the best research experience I have ever had. I have been involved in four different research projects and only now I feel like I know what mathematical research is all about. —2014 participant

The most memorable experiences were working with other black math students. It is an impossibly rare luxury for me to be able to work with black math students or even better, talented black math students. —2015 participant

Before this program, I was thinking about enrolling in a master's program. Now I am absolutely sure that I will be applying to PhD programs. —2016 participant

When we were able to define the group action on the induced Sperner's labeling, I was so happy that I could not stop smiling. It just reminded me how beautiful knowledge is, and how much I enjoy doing mathematics. —2015 participant

By making mathematics accessible and fun to all, we believe that more young people will be interested in it and will later consider mathematics as a possible discipline to study.

How successful are we? Measuring outcomes

MSRI measures success using qualitative and quantitative metrics. We collect demographic data on our program members and participants and have a dedicated staff person to analyze this data. For example, in the nine-year window from 2009–10 to 2017–18 (the most recent year with published data from the AMS): MSRI averaged 23% women among US-based research members (those in residence at MSRI for at least one month) while the AMS data reports 19% women among full-time doctoral faculty in all US math departments and 16% women among full-time doctoral faculty in only large public and private US math departments. For the same time period, MSRI had 28% of its US-based postdoctoral population identifying as women while the AMS reports 21% of non-tenured mathematicians at PhD-granting US institutions (and 20% at public and private large institutions). Of the US citizen and permanent resident postdocs, 16% have identified as members of underrepresented groups with 8% Hispanic and 7% Black, compared to 3% Hispanic and 3% Black among all US and permanent resident recipients of a PhD in mathematics.

Exit surveys indicate that the level of satisfaction for a participant in a long-term program at MSRI is extremely high. On a scale of 1 to 5, with five representing the highest score, satisfaction on average to the question, "Professionally my overall satisfaction with MSRI" is 4.75. These scores are the same whether the members are from underrepresented groups or not. A year-and-a-half ago we also added the following question to our survey: "MSRI aims to provide a supportive environment for all program participants, how satisfied were you with this aspect of your experience." The average score was 4.6 for women and members of other underrepresented groups, while it was 4.81 for men. Lastly, personal comments are very important to MSRI, and mathematicians are generally candid in their answers. They do point out areas where we can improve, and we take their comments to heart and make appropriate changes. For example, the Connections for Women has evolved considerably since its inception. It is now open to all and each program decides on its format. The program has even changed names while the purpose has

remained the same. Participants in MSRI's programs also share their enthusiasm with the activities described in this chapter, and overall they have strongly encouraged us to pursue the activities such as SRIM, ADJOINT, MSRI-UP and the Connections Workshops.

The continuing challenge

Building and maintaining an inclusive community is an ongoing challenge. It requires us not only to implement activities that support this goal but also to work to mitigate the effects of long standing inequities. Acknowledging and responding to the forces that have blocked these goals is our responsibility. Our efforts must be broad and intentional in all our activities. Experience shows that without continued vigilance and effort, the system reverts to old patterns. Pursuing, refining, and improving our activities, looking for new ways to move forward, sharing our experiences, and supporting each other leaves us hopeful that MSRI will help the broader mathematical community meet the challenge of creating and sustaining inclusive communities.

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Afterword

Make Progress Together

The communities in these chapters create a sense of belonging for both aspiring and established mathematicians. These welcoming spaces help students and colleagues continue in mathematics and find success in their academic pursuits and the profession at large. There *is* strength in numbers, after all. The collective power of communities just might offer a solution to the problem of underrepresentation by women and people of color in mathematics. *Together* we can make progress.

Start where you are with what you have.

- Think back to times in your career when you would have appreciated encouragement or validation. Now, offer that type of affirmation and support to a student or colleague. That action will not only advance those around you but will also give you a boost.
- Explore a community identified in this book that aligns with your interests and goals.
- Suggest a community in this book to a student or colleague who would benefit from the group and might not know of its existence.

Let your community grow.

- Bring people together to address a nagging omission in your department, institution, or discipline area.
- Write a grant to organize others around an idea, goal, or mission.
- Reach out and ask others to join you.
- Rotate out of a leadership position to allow another colleague an opportunity to develop professional skills.
- Welcome someone new into your group and show them they belong.

A heroic effort starts with a single step.
Aim for goodness.
Build a community.

This groundbreaking work explores the powerful role of communities in mathematics. It introduces readers to twenty-six different mathematical communities and addresses important questions about how they form, how they thrive, and how they advance individuals and the group as a whole. The chapters celebrate how diversity and sameness bind colleagues together, showing how geography, gender, or graph theory can create spaces for colleagues to establish connections in the discipline. They celebrate outcomes measured by mathematical results and by increased interest in studying mathematics. They highlight the value of relationships with peers and colleagues at various stages of their careers.

Together, these stories offer a guide—rather than a template—for building and sustaining a mathematical community. They call attention to critical strategies of rotating leadership and regular assessment and evaluation of goals and programs, and promote an ongoing awareness of the responsibilities of life that impinge on mathematical creativity and contributions.

Whether you are giving thought to starting a group, joining one already in existence, or encouraging a colleague to participate in the broader mathematical community, this book will meet you where you are—and move you beyond. It contains a plethora of ideas to foster a sense of belonging in the exciting discipline of mathematics.

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