EARLY CAREER

The Early Career Section offers information and suggestions for graduate students, job seekers, early career academics of all types, and those who mentor them. Angela Gibney serves as the editor of this section. Next month's theme will be your early career and the pandemic.



Good Ideas

Lessons Learned from the Bridge to Enter Advanced Mathematics Program

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Bridge to Enter Advanced Mathematics (BEAM) works to create comprehensive pathways for students from low-income and historically marginalized communities to become scientists, mathematicians, engineers, and computer scientists. Working with students beginning in

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Figure 1. Rising 8th graders Danielys (left) and Kenneth, attending BEAM's summer camp at Bard College (2016), work on polygons and Euler's partition function during class time.

middle school and running through college graduation, we've helped numerous students successfully enter STEM majors in college. Our focus is giving students access to deep mathematics, showing them a mix of pure and applied math, and introducing them to the idea of mathematical proof. Essentially, we want to bring out the excellence in our students.

At a time when concerns about equal access to education, systemic racism more generally, and access to levers of power (like STEM) are at a high point, we'd like to share some of the lessons we've learned to support those who'd like to begin to tackle these very difficult issues. We believe that mathematicians are positioned to make a real difference in their communities.

Why STEM Outreach Needs to Start at an Early Age

There is ample evidence that disparities in opportunity and achievement in STEM begin when students are young. While we often study differences in minimum proficiency (e.g., high school graduation), we rarely look at measures of advanced achievement, but the differences are stark. Consider:

- In 8th grade, on the National Assessment of Educational Progress (NAEP) exam, only 3% of low-income 8th graders score at the advanced level in mathematics, compared to 16% of more affluent peers. Achievement levels by race show a similar disparity.
- On the math olympiad qualifying track, we analyzed performance in New York State. Although

over 45% of New York State students attend a majority low-income high school, only about 2% of qualifiers for the second round (the AIME) were from such a school—and all of those were from one school in Queens, itself barely over 50% low-income, with a separate gifted program within the school.

• On the AP BC Calculus exam, only 1.2% of the students who receive a 5 (the top score) are Black; a randomly-chosen white high schooler is more than ten times as likely to earn this score as a randomly-chosen Black high schooler.

This last statistic is most stark in light of two telling facts. First is the prevalence of AP Calculus: over 400,000 students nationally take either AP Calculus AB or AP Calculus BC each year. Indeed, at Harvard, a staggering 91% of incoming undergraduates (regardless of intended major) have taken AP Calculus, 59% have taken AP Calculus BC, and 25% have taken a course beyond AP Calculus BC (such as multivariable calculus, linear algebra, or something higher). And yet, 70% of high schools in the top quintile for percentage of underrepresented minority students (defined in this study as Black, Latinx, Native American, and Pacific Islander) do not offer any form of calculus at all. How can we expect students to be prepared for STEM if their schools do not even offer such a course?

To be clear, we're not making an argument that calculus is the "right" course for high school students interested in STEM. What we are saying is that some students consistently have access to advanced and enrichment work in math and STEM more generally, and some students do not; then all of these students come together in the same college classrooms and are expected to complete the same majors. Thus, BEAM focuses on advanced work from an early age so that our students are prepared for that major.

Despite the clear challenges, there are signs that progress is possible. The percentage of Black students completing doctorates in STEM fields (including math) has been rising over the past few decades; access and outreach programs have made an impact, just slowly. There's strong evidence that we can open up more opportunity, especially if we start early.

How the BEAM Program Works

BEAM's students begin with our five-week, non-residential summer program for rising 7th graders, BEAM Discovery, where they learn mathematical thinking through courses on logical reasoning, creative problem solving, and applied math. In addition, each student takes a math fundamentals course, designed to reinforce school math while also showing students how to get away from rote procedures and instead think and reason about the math.

However, we believe success in math requires much more than just math! Equally important are the social, emotional, and identity components. Students make friends with others who love math and build the skills, confidence, and self-identity for success. We intentionally build community with college student counselors, activities, groupwork in classes, and more. We also strive to showcase mathematicians of color and expose students to career opportunities in STEM.

Students can then apply to continue to the BEAM Pathway Program, which supports them for nine years through college graduation. The first step is BEAM Summer Away, which is similar to BEAM Discovery but more: it's a threeweek, residential summer program where students dive deep into proof-based mathematics. Living together on a college campus builds friendships that last a lifetime and helps students develop their independence. They also start to see themselves as belonging in college and even learn basic terminology (such as "dorms," "quad," or "student union").

Thereafter, students are invited to a variety of year-round enrichment activities, including weekend classes, special trips, drop-in office hours, and more. In addition to enrichment math, we also provide a "Things You Need to Know" course based on the student's grade level:

- 8th graders: algebra
- 9th and 10th graders: study skills and life skills
- 11th graders: SAT prep and college application process
- 12th graders: college applications and college prep

Meanwhile, enrichment classes connect students back with the math they love: number theory, genetics, circuit design, programming, and more.

The idea of all of these programs is to provide real support to our students. Throughout high school, students receive individualized advising to apply to summer programs and internships that will support their continued study. Students also receive guidance on college applications, help visiting colleges, and tailored support with financial aid. For students who pursue STEM majors in college, BEAM provides advising and meet-ups throughout college.

This support pays off. To give some context, we recruit from partner middle schools that serve predominantly low-income and marginalized populations, and we have strict cutoffs for our programs regarding both family income and the level of access students have to learning opportunities. Our programs are 51% male and 49% female, 86% of students identify as at least one of African American, Latinx or Native American, and the median family income for BEAM's students is \$27,000 (in New York City and Los Angeles, to be clear). Over 65% of BEAM students will be the first in their families to go to college.

Meanwhile, the most recent BEAM students to graduate from high school were admitted to a diverse list of selective public and private colleges, including Barnard, Brown, Columbia, Cornell, Georgetown, Harvard, Tufts, Vanderbilt, and more. Overall, almost 70% of our college-bound students have enrolled at colleges ranked "very competitive" or higher as defined by *Barron's Profiles of American Colleges*.

How to DoThisYourself

We hope that many readers are inspired to work for change themselves. Without the engagement of STEM professionals, it is unlikely that we'll be able to address the systemic inequality of access to advanced learning.

We want to say this right up front: there are real and difficult challenges to becoming involved. Of course, any academic mathematician must either build institutional support for outreach or else balance outreach with the work that is valued in their department. Moreover, many academics come from privileged backgrounds, which can be genuinely problematic, reinforcing stereotypes and raising the likelihood of inadvertently harmful behaviors.

We can't share everything we've learned, but if you want to do this critical work, we'd like to offer some advice.

Before diving into the nitty-gritty, though, there are two overarching and very important steps to take.

First of all: find ways to engage and get to know the community you want to serve. Children's identity development is complex; things that might seem innocuous can be harmful to exactly the kids you want to serve. (For example: showing too much privilege or wealth; strongly expressing views that may be counter to those held by their parents; discussing current politics, even if you're "on their side," in a way that further marginalizes or objectifies the students.) Be aware that students might have significant trauma in their background, and an initial effort to talk about or teach something "relevant" can be more harmful than you realize. What if they have a friend or family member who was killed by police violence, for example, or someone close who was deported? Would that change your approach?

Ideally, if you are not yourself from the community you plan to serve, consider forming an equal partnership with someone who is to build a truly responsive program. Consider also volunteering under the leadership of someone else, especially initially.

A book you might find helpful is *Why Are All the Black Kids Sitting Together in the Cafeteria?* by Beverly Daniel Tatum. It has a nice blend of theory and research along with some practical advice. There are many other useful resources, depending on the population you hope to serve.

Our second recommendation prior to beginning your own program is to be clear-eyed about your goals and realistic about your strengths. As a mathematician, you bring an important strength to your program: you have a deep understanding of the kind of thinking that our work demands, and can effectively mentor students to go beyond algorithms to understanding. What are your other unique value-adds that will make your program effective, and how can you best leverage them? What are weaknesses where others can help fill in, or you can work to avoid?

It's not just about your own skills, but also about setting the right goals. Think beyond "I want to start a math program." Are you looking to start a program that will benefit all the kids in a classroom, maybe creating and doing some nice enrichment activities that will help them think more deeply about math? That program would be about general math literacy. On the other hand, perhaps instead you want to target students with STEM interest, or maybe you want to target those who are under-challenged in their math class regardless of their interest, and create a program specifically about accessing more advanced math and moving to STEM careers. Do you want your program to be specifically about math, or do you also want to focus more intentionally on community building and identity development? What about mentoring or advising to help students access other opportunities? These decisions will shape the program you build and all the other choices that you make.

You don't want to take on too much, but you do want to have a clear view of what success looks like, both for math and for other outcomes (such as college entry, STEM interest, friendships made, etc.).

Here are some additional big-picture suggestions we think can help you succeed and build a responsible and effective program.

First, build a diverse team. To the fullest extent possible, your team should be led by and representative of the members of the community you serve. Think broadly about this. Mathematicians, yes, but can you invite undergraduates to be involved? Can you engage parents and other family members of your students? They can be in the room and learn with their children; they can give feedback on the program, plan a potluck, coordinate carpooling, and much more.

Be humble. Before you begin, listen, listen, listen, and learn. Build ties with educators and the community first. Remember, there's a lot more to succeeding at math than just math!

Don't reinvent the wheel. Seek out individuals and organizations already doing good work in your community and partner with them. They'll likely have strengths, like outreach to families, that you might not have. Find curriculum resources (BEAM is developing some to share, and we'll link to others down below). Engage teachers: they understand their kids and how to engage them.

Beyond these overall principles, there are important things to keep in mind with the mathematics you will do with students. In particular, you don't want to assume norms and experiences that more privileged students have had. For example, they might not have seen a Sudoku before, or done a math team problem. At the same time, you might find that they have other touchpoints with mathematics instead, and we've found that many of our students come in with a strong culture of collaboration that helps them work very productively together. The ability to engage with mathematics doesn't rely on prior knowledge but rather on creative problem solving, insight, and interest, and so **traditional measures of mathematical skill may be inaccurate**. Each student's schooling context and background are different; it's so easy for seemingly trivial missing background knowledge to obscure a really deep thinker. For this reason, BEAM tries to focus on how much students grow at our program rather than judging them through early assessments of ability. Nonetheless, missing background knowledge is important to students' success; be prepared to bridge them even as you push students to think harder and go deeper.

Create a vibrant, engaging, and challenging environment; encourage students to lean into the struggle. Students should come away feeling that they have taken on a major challenge and succeeded. At BEAM, we constantly reinforce the idea that challenge is a part of learning and important to their success. When students find something difficult, we celebrate that feeling. Unfortunately, though, it's not quite that simple, and we still wrestle with just how much to push students. We want them to succeed to the greatest of their abilities, but we don't want to create stress to live up to "our" expectations or risk that they feel unworthy of the program if they don't think they're fully succeeding.

Listen to students. BEAM is always creating opportunities for small group discussions with students, and we give them surveys to tell us what they think about the program (including a very important question, "Is anything at the program making you uncomfortable?"). Student feedback is essential to how we improve. Moreover, we're now directly involving the many students who now return as staff! We also recommend giving students choices whenever possible: what to work on, what non-academic activity to join, what class to take. Giving them real agency can be liberating for them and leads to much greater investment in your program.

Use good educational resources, but beware of difficult phrasing. There are so many good resources for interesting, engaging problems: Math Pickle (mathpickle .com), the Julia Robinson Math Festival (jrmf.org), the book "Camp Logic" which is free under a Creative Commons license, and NRICH (nrich.maths.org) are just some examples. These can easily get you started. However, you should be wary of problem phrasing. Watch out for ancillary cultural elements that may not translate to students. Don't let complicated or mathematical phrasing get in the way of the core math students should do. There is often significant unnecessary cognitive load placed on students by asking them to parse mathematical terminology, and they spend their energy on that instead of doing the math!

Some final recommendations we'd like to present are to remind you that math isn't the only thing that matters.

Pay attention to logistics. So many logistical barriers can prevent student participation. Do they have a reliable

way to get to the program? Can they make the time? Are any costs a barrier (e.g., buying a program t-shirt)? Will they be hungry? Do they have a computer and internet at home? Consider simple changes that will improve outcomes. For example, having the program in the students' community (rather than, quite frankly, where it's convenient for you) might make a significant difference in participation.

It's about more than just math. For many of us, enrichment programs were our first time making friends through math. Consider the same for your students: if this matches your goals, how can you create a vibrant social environment for them? Beyond that social environment, also consider students' identities (and the danger of imposter syndrome). Think about how to foster a sense of belonging for them.

The most powerful experiences are those that build a community of kids who genuinely love math and who will support one another. A deeply caring community doesn't just tolerate difference, it welcomes it and is eager to discover more about everyone present.

This is just the beginning of our ideas after ten years doing this work. For more information and advice, as well as more details about BEAM's program, consider viewing our website (www.beammath.org) or our chapter in the book *Mathematical Outreach: Explorations in Social Justice Around the Globe.* We are also happy to provide advice to anyone beginning such a project.

Wrapping Up

There's a tremendous personal reward to helping students succeed at math. It might be a small program; maybe you and five students meet once a week after school to do some math together. It could be a larger program, bringing a few dozen students to your campus, or even bigger.

You can also get involved in existing programs. Perhaps a program needs someone to teach math on weekends; perhaps an outreach program is already running at your university. BEAM hires faculty for our summer programs, many of which are residential and thus hire nationally. There are many ways to get involved.

Above all, we hope that you will step up and bring your unique skills to this moment. Education is not a magic fix; the problems we face to achieving equity are much greater than just access and opportunity. However, while it may be just one part of the work to be done, it is work we are well suited to do, and we should step up to begin to effect real change.

Credits

Figure 1 is courtesy of Bridge to Enter Advanced Mathematics.

Author photo is courtesy of Erin Patrice O'Brien.

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