

The MathCEP Programs at the University of Minnesota: A Story of Longevity, Success, and Exemplary Outreach

By Evelyn Lamb

In the late 1970s, Macalester College in St. Paul, Minnesota, started a small accelerated algebra and geometry instruction program for middle- and high-schoolers in the Minneapolis–St. Paul area. After a few years, they asked the University of Minnesota to help them expand the program to calculus, but before they could, Macalester’s funding dried up. “I said, naively, ‘Let’s take the whole thing over,’” says Harvey Keynes, who was the associate head of the mathematics department at the University of Minnesota (UMN) at the time. After consulting with Willard Miller, then department chair, what is now known as the University of Minnesota Talented Youth Mathematics Program or UMTYMP (pronounced “um-tee-ump” by everyone involved) came to the UMN.

“We got the program started, and it was successful beyond belief,” Keynes says. In the program’s four decade history, it has served about 5,600 middle- and high-school students who have gone on to successful careers in math, yes, but also in other STEM (science, technology, engineering, and math) fields, as well as law, music, and business. This year, about 575 UMTYMP students in sixth through twelfth grade come to the University of Minnesota campus once a week for accelerated math classes. UMTYMP is the flagship program of the University of Minnesota’s School of Mathematics Center for Educational Programming, or MathCEP, which hosts a variety of other math outreach and training programs and received the 2018 AMS Award for an Exemplary Program or Achievement in a Mathematics Department.

Evelyn Lamb is a freelance math and science writer based in Salt Lake City. Her email address is rootsofunityblog@gmail.com. For permission to reprint this article, please contact: reprint-permission@ams.org. DOI: <http://dx.doi.org/10.1090/noti1682>

Origins

Keynes was part of a cohort of faculty that came to UMN in the late 1960s, mostly from the east coast, where many of them had gone through accelerated public high school programs that had jump-started their careers. Minnesota did not have similar programs, so as faculty members’ children grew up and went to school, there was strong support from the faculty to get such a program running. Keynes says the political climate at the time contributed to a post-Vietnam War slump in interest in STEM majors, so faculty were also eager to attract and work with students who were genuinely interested in math and other STEM fields. When the opportunity came, they were ready to support it.

Peter Olver, the current head of the mathematics department, says the program fits perfectly into the mission of the university. UMN is the land-grant university in Minnesota, and with that designation comes a strong feeling that the university should be dedicated to serving the needs of residents of the state. Shortly after the program was founded, the Minnesota state legislature gave it a specific line item in the state budget as a “state special” associated with the university. It is one of only two that are still in the budget.

UMN quickly saw the benefit of the program. “It wasn’t the primary reason we started it, but the University of Minnesota loved the graduates,” Keynes says. MIT, Stanford, Harvard, and Berkeley are among the most popular schools for UMTYMP graduates, but UMN tops the list. “These were kids who may never have considered coming to the University of Minnesota, but they liked what they saw here in UMTYMP,” Keynes says.

There were some concerns early on that the program would hurt local schools, taking some of their strongest math students out of the classroom. “There was a lot of politics involved,” Keynes says, in convincing schools and

teachers that the program would not be a threat. “It took a lot of time to work it out, but we persisted.”

The program is more or less unique in the country. The University of Minnesota has some attributes that make it particularly suited for a program like this. Many states chose to start a new university as their land-grant school, but Minnesota chose not to, so UMN is both the land-grant university and the major public university in the state. It is also in the state’s largest population center; about two thirds of Minnesota’s population lives in the Twin Cities metropolitan area. “You need a critical mass of students to get such a program running,” says Olver. Having a large population to support the main branch of UMTYMP has allowed the school to offer the program at some of the university’s other campuses as well, though the vast majority of students go through the Twin Cities program.

When Keynes was looking at retiring, the department planned on hiring a senior mathematician from outside the university to take over. Jonathan Rogness had started teaching at UMTYMP as a graduate student. “I went to a small liberal arts college, and I always thought I was headed back to a place like that after I finished my PhD,” he says. But he enjoyed UMTYMP so much he stayed on as a postdoc after graduating, and his years of experience with the program made him a good fit to direct MathCEP and UMTYMP. “I always say this is the only job I would have taken at any large research university,” he says. With UMTYMP and MathCEP, he gets to develop close relationships with students over the course of the program.



Former UMTYMP director Harvey Keynes (r) and current director Jonathan Rogness (l) prepare for a lesson on sphere packing.

UMTYMP Today

The first two years of UMTYMP are an accelerated trip through algebra, geometry, and precalculus, completing Minnesota state math requirements for high school graduation. Recently, the median age of students in the program has been decreasing. As the state math curriculum has moved toward emphasizing algebra earlier, more students have been academically ready for the program



Students learn about origami and mathematics in a Saturday enrichment program.

by sixth grade. “There’s a little more variability with the sixth graders than the seventh or eighth graders in terms of their ability to handle such a long class,” Rogness says. The entrance exam cannot test maturity, so he talks to parents before the program about what to expect and whether their kids are ready for the format of the program.

In the early days, UMTYMP met twice a week after school, but it is currently only once a week to fit more easily into student schedules. The first two years of the program are taught by local teachers, many of whom are master’s students in mathematics with an emphasis in math education. Rogness relies on their expertise teaching young students. “I’m not about to start micromanaging,” he says. “We hire good teachers who are enthusiastic about math and want to share that with students, and then I get out of their way.”

After the first two years, UMTYMP students spend the next three years in an accelerated calculus sequence, covering single-variable calculus, multivariable calculus, and linear algebra. The final semester is a rotating course in combinatorics, number theory, or some other advanced topic. Taking these rigorous math content courses allows UMTYMP students to start their college careers with more advanced math classes and try more different things while they have a chance in college. Students who enter UMTYMP as sixth- or seventh-graders finish the program before their senior year of high school. Many of them take advanced math classes at UMN after graduating from the program.

Creating An Ideal Environment

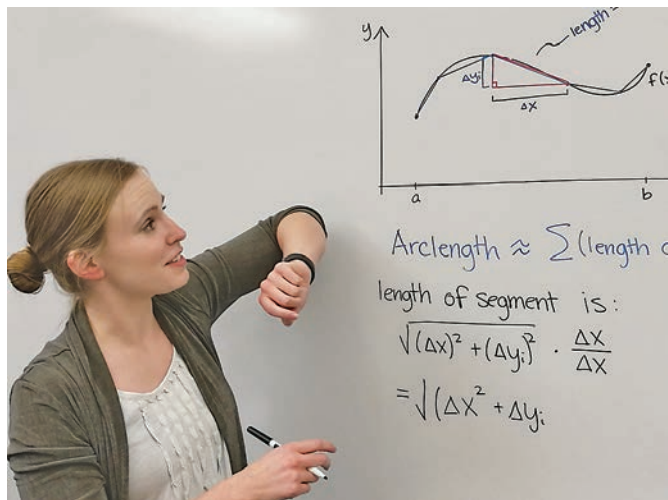
UMTYMP’s history is marked by great care to create a good environment for helping students have a positive experience as they took on challenging math courses. “They were so thoughtful about the efforts to build that program and learn at every step,” says Theresa Wise, retired Chief Information Officer of Delta Airlines and the first female student to graduate from UMTYMP [See sidebar on page

581.J. Several other girls started the program with Wise, but attrition rates, for both boys and girls, were higher at that time, and Wise was the only girl to graduate in her class. Since Wise was a student, the program has consistently worked to get a more even gender balance in the program and increase retention rates for all students.

In 1988, UMTYMP was awarded a grant from the Bush Foundation to increase the number of girls in the program and improve their experiences during the program. “A lot of things they did have become part of the overall program for everybody,” Rogness says.

Today, about 35 to 40 percent of admitted students are girls. In order to keep classrooms from being dominated by boys, if there is a class that has a large gender imbalance, UMTYMP creates an all-boys section to maintain a more balanced gender ratio in the other sections so no girls will be in classes where they will feel isolated. Rogness says the practice is based on research that shows that girls feel more comfortable in classes when there is a critical mass of female students in the room.

UMTYMP also started an informal mentor network for girls, where older students are paired up with younger ones to help them when they suddenly come to a concept that really stumps them or get that first low test grade. They have a few girls-only UMTYMP events each year, with fun activities such as a screening of the movie *Hidden Figures*, to help girls develop friendships and supportive relationships with other girls in the program.



MathCEP postdoc and former UMTYMP student Melissa Lynn teaches calculus.

The program incorporates active learning and group work, encouraging students to see math as a cooperative endeavor. “In my normal high school life, I would downplay how much I liked math, especially as a girl” says Melissa Lynn, an UMTYMP alumna who is now a MathCEP

postdoc. Group work in UMTYMP allowed her to work on math collaboratively with other students who were just as excited about math.

In addition to typical problem sets, UMTYMP calculus sequence students present some “professional” problems, often proof-based, with more thorough written explanations. “I think learning mathematical writing through that helped me go into proofs-based classes later on,” Lynn says. “Seeing other students in my classes, and later as a grader, I learned that not everyone comes into higher-level math classes with the ability to write proofs like that.” As an instructor who has worked with many students both in and outside of UMTYMP, she appreciates how unusual it is for young students to learn to write math well. “It’s incredible how good these students are at writing math,” she says.

Brooke Ullery, an UMTYMP alumna, says the program prepared her for a career in math research by teaching her how to work hard on math problems. She is currently a postdoc in mathematics at Harvard University. As a teacher, she sees that many students don’t know how to work on problems that aren’t the same as problems they’ve already seen before. “They have to learn how to think about different strategies, to do problems in a lot of different steps,” she says. “That’s one of the biggest leaps people have to do going into advanced math, and it’s something UMTYMP forced me to do earlier on.”

MathCEP

UMTYMP is the best known program of the broader MathCEP center, which offers enrichment events for students from fourth grade through high school, along with teacher training and postdoctoral positions.

Some of the most widely attended programs are the department’s Saturday morning math enrichment events. Offered about once a quarter, they bring students, teachers, and families from around the area to the university for math activities led by MathCEP and UMN graduate students, postdocs, and faculty members.

One recent event focused on topology and graph theory. Students began by looking at Euler’s classical Bridges of Königsberg puzzle: Was it possible to cross over all the bridges in Königsberg exactly once? Euler proved it was impossible, and after exploring the situation and figuring out why it was impossible in eighteenth-century Königsberg, students looked at an example closer to home, studying the topology of the bridges of Nicollet Island, situated in the Mississippi River a few short miles from the UMN campus in Minneapolis.

MathCEP also sponsors a Girls Excel in Math (GEM) program for 4th–6th grade girls. GEM and the Saturday morning enrichment programs originally started as a way to prepare and encourage students who might someday apply for UMTYMP, but the aim is to help students encour-

About 35 to 40 percent of admitted students are girls.



A Girls Excel in Math student deciphers a message during a cryptography lesson.

ter interesting math in a fun environment, whether or not the students decide to focus on math as they get older.

Recently, MathCEP has offered summer camps for high school students, including a math modeling camp run jointly by the Institute for Mathematics and its Applications, also located at UMN. “For most of them, it’s their first experience with a really open-ended problem,” Rogness says. One year, the program opened with a challenge to design the best recycling program for a city. Students’ first instinct was to start searching for a cut and dried answer on the internet. “Thirty-five minutes later they start to wonder, what does best really mean?” Rogness says. These open-ended problems, on topics from recycling to white-nose syndrome in bats to Twin Cities area bike-share programs, help students understand the importance of math modeling in everyday life.

The UMN Master of Math with an emphasis in math education program is not officially under the MathCEP umbrella, but Rogness is the faculty advisor for the program, and students in the program often teach at UMTYMP and other MathCEP activities. In the past few years, MathCEP has been able to hire postdocs as well.

Continued Growth

Mike Weimerskirch is the MathCEP Director of Educational Innovation, and since joining the department a few years ago, he has been working on easing the transition from high school to college for students in entry-level math classes. “We’ve got all these good things at the K-12 level with students and teachers, and then there’s the master’s program and the MathCEP postdocs, but there was sort of this gap at the undergraduate level,” Rogness says.

Weimerskirch’s first mission was to improve retention rates in introductory math courses. He overhauled the university’s precalculus sequence, replacing lecture-style classes with more of an active learning approach. He has been training teachers to teach the new courses and creating a video textbook for students in the class. As the university has transitioned to the new approach, re-

tention rates in the sequence have improved, and more students are continuing from those courses into calculus. Beyond the retention numbers, though, he sees an attitude difference in students in the active learning classrooms compared to the traditional lectures. “They’re used to the fact that they have some skills to try some stuff, and it may or may not work, but they’re willing to engage in mathematics,” he says.

High school calculus teachers have a lot of training in education and pedagogy but sometimes little math background past calculus; college calculus teachers tend to know a lot of math beyond calculus but often have little preparation for the classroom. “I really see this as an opportunity to bring the high school community and the college community together to work on things,” says Weimerskirch, who taught high school math before coming to UMN. Educators at both levels have a lot to offer each other. Weimerskirch hopes that he and his colleagues can create materials that will improve precalculus and calculus classes in both high schools and colleges.

Recently, Weimerskirch started collaborating with faculty members at several universities around the country to develop open educational resources for both precalculus and calculus classes. It started when Weimerskirch was trying to choose an online homework system for calculus classes at UMN. After finally coming to a decision, he started to get emails from colleagues at other universities about other possibilities and potential collaborations. “It just spread, and suddenly I had people from Nebraska writing to me: ‘Hey, this is a great workshop. When are we doing it?’ I didn’t know I had volunteered to organize a nationwide workshop, but apparently I did.” The group, which calls itself the Collaboration for the Advancement of Learning Calculus, or CALC, has members at about a dozen schools and has met twice so far to exchange ideas and share resources for teaching precalculus and calculus.

Lasting Impacts

With 5,600 UMTYMP alumni and even more students and teachers who have participated in other enrichment and training programs, MathCEP has a prominent place in the mathematics community, especially in Minnesota. “It’s one of the great things about the University of Minnesota, and particularly the math department,” Olver says.

“One of Harvey’s favorite things to tell people is that 110 percent of our students earn degrees in STEM fields,” Rogness says. There are enough alumni that double major in multiple STEM fields or get advanced degrees that if you take the number of STEM degrees and divide it by the number of students, you do get a number larger than one. Historically, about 28 percent of UMTYMP student major in engineering and 18 percent in math. Computer science, physics, and other STEM majors are also high on the list, though many students go into law, music, or other disciplines as well.

The students in the program are interested in math, but they are also involved in theater, music groups, and many other interests, like any group of motivated high

school students. “It’s nice to see these ordinary kids do extraordinary things,” Keynes says.

An indication of how positive the experience is for students is the number of UMTYMP students, like Melissa Lynn, who end up coming back to teach in the program. Lynn completed UMTYMP in her junior year of high school and took an abstract algebra class at UMN during her senior year. She went to college at the University of Chicago with the intention of eventually going to graduate school to be a math professor. “I felt like I was set up to succeed there,” she says. She went to UCLA for graduate school in math. “About halfway through the program, I started re-evaluating,” she says. “I was more excited about the teaching activities than the research.” After getting her PhD she wanted a teaching-focused job, and ideally she would be able to move back to the Twin Cities to be closer to her family. The MathCEP postdoc was a good fit for her, and she is now teaching there.

“MathCEP seems like the ideal preparation for me,” Lynn says, as she looks to prepare herself for teaching-focused tenure-track jobs. During graduate school, she didn’t have many opportunities to be the primary instructor in a course, and at UMN she teaches both UMTYMP and other UMN courses. “It’s not a super heavy teaching load, so we can really focus on doing it well.” MathCEP provides support and resources for experimenting with different teaching formats. She is currently involved in revamping the UMTYMP multivariable calculus class, replacing the current textbook with an online, interactive resource.

Outside of teaching, MathCEP postdocs have a lot of latitude in the activities they work on, from continuing their own research to participating in other outreach activities to supervising student research projects. Lynn has been especially involved in the latter, working with both UMN undergraduates and UMTYMP students on research projects in knot theory and number theory. She is also an editor for the *Minnesota Journal of Undergraduate Mathematics*, an undergraduate research journal the school recently started publishing.

Few top-tier research universities like UMN have such a strong commitments to intensive and extensive educational programming, and Olver says it’s a draw for the department. MathCEP and UMTYMP make it easy for UMN faculty to plug into an already thriving, well-supported outreach program. “Whenever we’re recruiting tenure track faculty, this is one of the main things I mention,” Olver says.

MathCEP has had an enormous impact on math education in the Twin Cities for 40 years, and Rogness is proud of the environment the program fosters. “It’s not that every single day is perfect,” he says, “but there are a lot of times when you walk in, and it’s just so much fun to be with all these kids who really like math.”

Photo Credits

Sidebar photo courtesy of Theresa Wise.

Article photos courtesy of University of Minnesota.

See the official AMS 2018 Award for an Exemplary Program or Achievement in a Mathematics Department citation on page 550.

An UMTYMP Alumna's Flight Path

Theresa Wise was an eighth grade UMTYMP student in 1980, the first year the program was held at UMN. She went to public school, and no one in her family had yet graduated from college. She was a good student in her math classes and liked puzzles as a kid but didn't have any exposure to math as a creative, living subject. UMTYMP changed that. "What this opened was absolutely irreplaceable," she says. She still remembers taking the entrance exam, which tested reasoning skills and a few computational concepts but no advanced math content. She likely would not have gotten into the program if it required anything beyond typical middle school math, and she appreciates the fact that Keynes and others involved with UMTYMP thought carefully about how to find kids who would thrive in the program, whether or not they had already been accelerated in math classes.

After becoming the first girl to complete the full UMTYMP cycle (from grades 8-12), Wise went to St. Olaf College as a premed student and earned a bachelor's degree with a double major in chemistry and math. "When I got to college I wanted to try a bunch of different things, but because I had that rooting in mathematics to begin with, it was natural to continue math as I explored other things," she says.

By the time she graduated, she realized that she wanted to continue in math rather than becoming a doctor. She was still interested in medicine, though, and started a PhD program in applied math at Cornell University, intending to do math modeling with medical applications. Along the way, she ended up doing an internship with Northwest Airlines and getting interested in understanding the logistical challenges of the airline industry. Her first job after graduating with a PhD was doing mathematical modeling for the airline industry, and she ended up staying in the field. Eventually she saw that the largest logistical challenges in the airline industry required more than math modeling; they also required significant advances in information technology, and she expanded her focus to include IT problems as well. She was Chief Information Officer for Delta Airlines, also responsible for Operations Research, until her retirement.

Wise sees UMTYMP as a huge factor in her future educational and career successes. "It's so hard to know how things would look without that experience," she says, but she doubts she would have ended up in a math career without it. She believes one of the reasons is that it kept her challenged and engaged. She says there are several points in the standard math course sequence where bright students can lose interest in math and related fields. The accelerated UMTYMP program can keep students from hitting those points of boredom when they are young, and by the time they're in college, they are ready for a broader array of interesting advanced classes. "If the first college experiences with math are really fascinating experiences, that inspiration is there to keep going," she says.

Aside from the math itself, though, the program fostered good attitudes towards learning and hard work. "I think it's amazingly good for kids in middle school or high school to be in a situation in which they are academically challenged and not necessarily number one," she says. Sometimes, high-achieving students get used to the "reward" of always getting an A and are discouraged when they get to a level where they no longer get that reward on a regular basis. "One of my only 'B's' through high school or college was given to me by Harvey Keynes," Wise says. "How good to learn at that pretty young age that it's just about learning. It was a lesson about being stretched and not being afraid of being stretched."



UMTYMP alumna Theresa Wise.