2020 Award for an Exemplary Program or Achievement in a Mathematics Department

The **Department of Mathematics at the Massachusetts Institute of Technology** is the recipient of the 2020 AMS Award for an Exemplary Program or Achievement in a Mathematics Department.

Figure 1. PRIMES students at an annual conference at MIT.

Citation

The 2020 Award for an Exemplary Program or Achievement in a Mathematics Department is presented to the Department of Mathematics at the Massachusetts Institute of Technology. The MIT Mathematics Department is being honored for its Program for Research in Mathematics, Engineering, and Science for High School Students (PRIMES), which provides significant research experiences and mathematics enrichment to high school students locally and globally, with particular attention to increasing the representation of women and underrepresented minorities.

PRIMES is a free, year-long research and enrichment program for high school students, created in the MIT Mathematics Department in October 2010. The program's innovative, year-long model for guiding high school student research is being used also in computer science, bioinformatics, computational and physical biology, genomics, and neuroscience. PRIMES students use their knowledge of mathematics and computer programming to solve problems related to cancer research, Internet security, traffic control, refugee migration, brain research, laser engineering, and many other applied fields. PRIMES Circle and MathROOTS help attract members of underrepresented groups to pursue careers in the STEM fields. A 2015 article about PRIMES, which sums up its experience and provides advice for setting up similar programs in other institutions, published in the *Notices of the AMS* (Pavel Etingof, Slava Gerovitch, and Tanya Khovanova, "Mathematical Research in High School: The PRIMES Experience," *Notices of the AMS*

62, no. 8 (2015)), has been translated into Mandarin and summarized in Spanish. In 2017, the PRIMES-Switzerland program was established at the University of Geneva and ETH in Zürich.

PRIMES includes five sections. MIT PRIMES offers research projects and guided reading to students living within driving distance from Boston. Program participants work with MIT researchers on exciting unsolved problems in mathematics, computer science, and computational biology. PRIMES-USA is a distance mentoring math research program for high school juniors from across the United States (outside of Greater Boston). PRIMES Circle and MathROOTS are math enrichment programs for high-potential high school students from underrepresented backgrounds or underserved communities. PRIMES Circle is a spring-term program for local students from Greater Boston. MathROOTS is a free two-week residential summer program. CrowdMath, run jointly with Art of Problem Solving, is a massive collaborative year-long online research forum open to all high school and college students around the world.

PRIMES has three main goals:

1. To give talented high school students a unique opportunity to experience the joy and beauty of mathematical research
2. To inspire them to pursue careers in the mathematical sciences
3. To diversify the pool of students interested in mathematics by providing additional opportunities for promising young women and underrepresented groups.

Between 2011 and 2019, 281 students participated in MIT PRIMES and PRIMES-USA. All of the 276 research projects completed were presented at nine annual PRIMES conferences, 179 research papers have been posted online, and at least 31 have been published in such journals as *Representation Theory*, *Journal of Algebra*, *Journal of Algebraic Combinatorics*, *Journal of Combinatorics*, *Journal of Integer Sequences*, *Electronic Journal of Combinatorics*, *International Journal of Game Theory*, *Transactions of the AMS*, *College Mathematics Journal*, *Topology and Its Applications*, *Involve*, *Math Horizons*, *Cell Reports*, *Letters in Biomathematics*, *Physical Review E*, and *PLoS Computational Biology*. Several PRIMES students have won prizes and awards at the MAA Undergraduate Student Poster sessions, at the Intel International Science and Engineering Fair, in the Siemens Competition in Math, Science, and Technology, and in the Intel/Regeneron Science Talent Search. Four Davidson Fellow Laureates and eight Davidson Fellows have been PRIMES participants.

From 2013 to 2019, eighty-four students completed the PRIMES Circle program, including sixty female, fourteen African American, and nine Latino students. From 2015 to 2019, one hundred students completed the MathROOTS program, including forty-four female, forty-seven African American, and forty-nine Latino students. Among the eighty participants in the 2015 to 2018 summer programs, forty-two were admitted to MIT, and twenty-eight enrolled. In 2019, forty out of 112 PRIMES students were female, and twenty-one were minority students

About the Program

In October of 2020 MIT PRIMES, founded by Pavel Etingof and Slava Gerovitch, will celebrate its tenth anniversary. It started as an experiment in year-long math research by high school students with just twenty-one local participants. The experiment proved very successful, with the program growing more than fivefold in ten years and expanding both nationally and internationally.

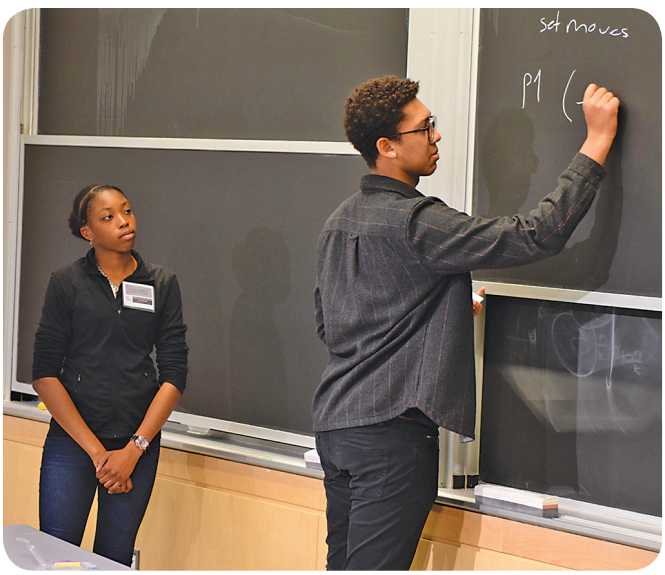

Figure 2. PRIMES Circle students Laura Clervil and Sekai Carr giving a talk at an annual conference at MIT.

Figure 3. MathROOTS students at a study session on the roof of the MIT Math Department's building.

PRIMES offers real, not toy, research projects to high school students and provides academic mentorship for a full year. The program builds collaborative teams that include faculty, postdoctoral researchers, graduate students, undergraduates, and high school students, promoting partnership and wider outreach in the mathematical sciences community.

Keys to the PRIMES success are thorough preparation, continuous review of research projects, and effective mentorship techniques. Choosing a research project for a high school student is no easy task. PRIMES's experience shows that most fruitful are the projects that have an *accessible beginning* with relatively simple initial steps; *flexibility* in switching among several related questions; *computer-assisted exploration* aimed at finding patterns and making conjectures; *faculty advisor involvement*; relation to the *mentor's own research area*; understanding of the *big picture and motivation*; a *learning component* that encourages the student to study advanced mathematics; and *doability* within a year-long time frame.

Effective mentorship involves striking a balance between guiding the student and allowing independent thinking, being attuned to the learning and research style of every student, and regularly reviewing the project progress and adjusting its scope, if needed. Head mentor Tanya Khovanova regularly meets with students to gather their feedback and help with communication and motivation issues.

PRIMES has accumulated experience in supervising both individual and group (two to three students) research projects, guided reading groups, a larger research group (a six-student computer algebra lab), and an open online forum with a varying group of participants (CrowdMath). The program regularly conducts both internal and external evaluations via surveys and interviews with student participants.

An award-winning student wrote in her testimonial: "PRIMES is an incredible opportunity that allows high schoolers to do what they would never normally have the chance to do: research, while also providing the guidance and encouragement that is crucial for success. Ultimately, PRIMES has truly cemented my interest in math, and it is for this reason that I would definitely encourage any student similarly passionate about mathematics to apply!"

Female and minority students from PRIMES Circle commented in their survey: "My experience in MIT PRIMES Circle has allowed me to appreciate mathematics from a new perspective and become fascinated by how beautifully simple a complex idea can become. The best part was walking out of the program with better developed critical thinking skills and a mathematical toolbox that I could apply to the real world." "To me, PRIMES Circle is a wonderful opportunity to learn what it is like to be a real mathematician."

Minority students attending MathROOTS also commented on their experience: "Personally, I thought it was awesome seeing people from a multitude of backgrounds all interested and passionate about math." "Before MathROOTS, I was unsure about MIT, but now, I feel like it's my home. I hope I get to return there soon."

About the Award

The Award for an Exemplary Program or Achievement in a Mathematics Department was established by the AMS Council in 2004 and was given for the first time in 2006.

This award recognizes a department that has distinguished itself by undertaking an unusual or particularly effective program of value to the mathematics community, internally or in relation to the rest of society. Departments of mathematical sciences in North America that offer at least a bachelor's degree in mathematical sciences are eligible. Through the generous support of an anonymous donor, the award carries a cash prize of US$5,000. The award is presented by the AMS Council acting on the recommendation of a selection committee. The members of the 2020 selection committee were George E. Andrews, Maria M. Klawe, Richard S. Laugesen, Brea Ratliffe (Chair), and Ulrica Y. Wilson.

Credits

Figures 1 and 2 are by Slava Gerovitch.
Figure 3 is by Sandi Miller.