

All Girls All Math

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All Girls All Math is a summer math camp for high school students held each year at the University of Nebraska–Lincoln (UNL). Now in its 24th year, the camp offers high school students with a strong interest in mathematics an opportunity to learn mathematics not studied in their schools while immersed in a community of other young students who share their interest in mathematics. The program has proven to be an outstanding experience, not only for the participants but also for the UNL students who are employed as tutors and coordinators and for alumnae who return to teach the camp.

The Beginning

When coauthor Judy Walker joined the UNL mathematics department in 1996 as a new Assistant Professor, she was one of only three women in the department. The others were Wendy Hines, who was also an Assistant Professor, and Professor Sylvia Wiegand, a future President of the Association for Women in Mathematics. Eager to contribute to making mathematics a more attractive profession for women, Walker and Hines began discussing possible activities that would encourage high school girls to consider mathematics as a college major. Two ideas were central in developing the All Girls All Math summer camp: introducing new mathematical concepts at the high school age and meeting new peers who also love mathematics. They wanted to help participants learn mathematics that was outside of the usual high school curriculum—the camp’s content should be accessible to high school students without

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being either remedial or accelerated—and, ideally, it would be connected to their own research. They also had the idea that girls would benefit from an opportunity to meet other young girls who shared their love of mathematics, learning this new mathematics in an environment free of the social tensions that are often present in their own classrooms.

To make the proposed All Girls All Math summer camp a reality, Walker and Hines needed staff and financial support. They applied for and received a grant from the Mathematical Association of America’s (MAA) Tensor program. Additional funding was provided by UNL’s College of Arts and Sciences and Department of Mathematics. Staff support was provided by UNL’s Center for Science, Mathematics and Computer Education (CSMCE).

Forty Nebraska high school students applied, and 14 highly talented girls were selected to attend the weeklong camp, which was held in July 1997. Walker taught a course on number theory and cryptology, and Hines taught a course on fractals and chaos. The campers lived in a university residence hall, ate dormitory food, studied mathematics, and made friends with girls like themselves who enjoyed mathematics. For many campers, this experience was their first time being part of a community of peers who shared their interest in mathematics—a welcome relief from the sense of isolation they often felt in their own high schools’ math courses.

Eager to build on the success of the first camp, Walker and Hines proposed having two camps in Summer 1998 and offered All Girls All Math as a national program, reserving about half of the spots for Nebraska students. Advertising nationally, applications increased significantly, and 34 young women had the opportunity to participate in one of two camps held that summer.

UNL has now hosted 35 camps over 24 years. In total, about 780 high school girls have participated in All Girls All Math. The first nine camps averaged 14 students per camp, while over the past decade the program averaged 26 students per camp until 2020, when the COVID-19 pandemic required a new approach. A handful of participants have come from countries outside of the US.

The Camp and its Curriculum

The All Girls All Math (AGAM) summer camp starts on a Sunday afternoon as campers arrive throughout the day, check into the residence hall and with camp coordinators, spend time getting to know one another, and play games. Sunday evening, campers are welcomed by the chair or another leader from the Department of Mathematics at UNL. To motivate the students to quickly engage in problem solving and recognize the benefit of working in groups, a few problems are posed, and the participants are offered prizes for their solutions. The activity supports team building as the students form problem-solving groups and share the prizes if they win.

Campers participate in the cryptography course created by Walker for three hours each morning. Typically, there is a one-hour lecture followed by two hours where campers work together on problem sets in groups of two or three. The course begins with a historical discussion of cryptography as they explore the Spartan Scytale and the Caesar cipher and, more generally, substitution ciphers. The participants study modular arithmetic, greatest common divisors, and solve linear congruence equations. They learn to use Maple to do computations and engage in a discussion about exponentiation modulo n and the idea of “fast exponentiation.” Much of this is done by hand so they understand it is feasible before they begin using Maple. The group moves on to Euler’s theorem and a discussion of RSA public key cryptography. Students get excited by the idea that all of the mathematics they have studied has such a practical application. The campers recognize that encryption using small primes is not secure, but that using Maple, it is easy to find relatively large primes, while factoring a large number into a product of primes remains hard. The campers have fun using public keys to send encrypted email to one another. The course ends with a scavenger hunt where the clues are given in code.

Feedback during the camp’s early years resulted in replacing the chaos course developed by Hines with a series of minicourses (stand-alone three-hour courses). In the afternoons, the minicourses offer campers the opportunity to sample different areas of mathematics. Over time, quite a few minicourses have been offered, with topics such as aerodynamics, knot theory, fractal geometry, Boolean networks in biology, and the mathematics of the game of Set. Feedback from campers enables the organizers to refine and improve the minicourses that are most successful and retire those that do not work well in the camp setting.

Recreational activities, such as tours of the volleyball complex in the Devaney Sports Center and rock climbing at the UNL Outdoor Adventures Center, are held in the evenings to help build camaraderie [3].

The Case for Supporting Women in Mathematics

Most mathematicians strongly support the idea that for the mathematics profession to be healthy, it must succeed in developing mathematical talent among all groups. In particular, mathematics will benefit if more women earn undergraduate and graduate degrees in mathematics. However, as reported in the September 2020 issue of the *AMS Notices*, only 29% of the doctoral recipients in 2017–2018 were women [2]. But that’s actually down from the high of 32% in 2014. Remove the statistics and biostatistics data, and one learns that in mathematics and applied mathematics, women earn only 24% of the PhDs. The results are even more disappointing when restricted to US citizens: only 21.6% of 746 PhDs awarded in 2017–2018 to US students went to women.

Walker and Hines recognized that a program like they envisioned could contribute to attracting high school girls to mathematics majors, or more generally to STEM (science, technology, engineering, and mathematics) majors in college. In the mid-1990s, research findings began to show that girls achieve more in an all-women environment. The probability that a woman college student will obtain an advanced degree is positively associated with the percentage of faculty at her undergraduate institution who are women [6]. Girls-only extracurricular programs, such as summer camps, have been shown to favorably influence a number of mathematics-related outcomes for participants, such as greater STEM participation [5, 8].

Research also shows more self-confidence in the pursuit of engineering majors among gender-segregated educational settings. While career aspirations are similar for graduates of single-sex and coeducational schools, a divide occurs when it comes to engineering [7]. Single-sex school alumnae are more likely than their coeducated peers to state that they plan to become engineers. In 10 independent schools that were studied, single-sex alumnae were three times more likely than women graduates of coeducational schools to report that they intended to pursue a career in engineering [7].

Krings [4] found a correlation between the number of women who earned master’s degrees in mathematics and the percentage of women at that university, whether faculty, administrators, or fellow students. This finding suggests that high school girls are more likely to pursue mathematics if they have more women role models and meet more women mathematics students like themselves [3].

Benefits to Current and Former UNL Students

While the obvious benefit of AGAM is to the high school students who participate in the program, there is also a clear benefit to UNL undergraduates, graduate students, and PhD alumnae.

After a few years, Walker and Hines realized that they could not sustain the program by being its instructors every

summer, and decided instead to hire women who had earned their PhD at UNL and were now faculty members at other institutions. To date, at least 25 alumnae have had the opportunity to return to Lincoln and teach the camp.

Katie Johnson, Associate Professor of mathematics at Florida Gulf Coast University (FGCU), who earned her PhD from UNL in 2012, was a camp instructor in 2013 and 2017. In her current position, she helps organize GEMS (Girls in Engineering, Math, and Science), a weekend program for middle school students in which they complete hands-on STEM activities. She said her experience at UNL influenced her work at FGCU by encouraging her to not shy away from difficult topics that are not part of the usual K–12 curriculum, emphasizing the importance of such experiences for middle school students, and demonstrating that when done well, these programs can be lots of fun for everyone involved.

Erica Johnson, Associate Professor of mathematics at St. John Fisher College, has helped teach the codes course at least seven times since graduating from UNL in 1998 and writes: “It has been a personal and professional pleasure to have been involved with AGAM through the years. Working with curious students is its own reward; equally rewarding was being part of an experience that brings young women together and creates a space where they are encouraged to love math and science.”

To support students as they engage in problem solving, AGAM hires UNL women graduate students to lead problem-solving sessions. In addition, the graduate students live in the dorms with the campers, serve as chaperones, and, quite naturally, serve as mentors for the girls. To date, more than 20 UNL graduate students have participated in the program.

While the camp is organized by a talented staff in the CSMCE with expertise in event planning, each year an undergraduate is hired to serve as the camp coordinator.

Amy (Been) Bennett, now a postdoctoral fellow in the UNL Department of Mathematics, was involved with AGAM as an undergraduate coordinator during three of her four years as a mathematics major at UNL, from 2010 to 2012. Bennett remembers how the students arrived feeling a bit intimidated, but left as part of a vibrant group of problem solvers—and friends.

In the early years, the undergraduate coordinators were traditionally mathematics majors. With the recent expansion of summer REUs and mathematics internships, the CSMCE has turned its attention to recruiting secondary education majors to serve as the undergraduate coordinators. The immersive weeklong camp gives these aspiring high school teachers the experience of how to teach and lead high-school-aged students, as well as the opportunity to act as a mentor and role model to them. The impact of the camp on the undergraduate coordinator can be just as valuable as on the participants.

Lessons Learned from Alumnae

Keeping in touch with AGAM alumnae can be a challenge, as the initial address the CSMCE has for the participants is their parent’s address. As they transition to college, graduate school, and work, the campers move, and it is hard to keep track of them. The program surveyed alumnae in 2003, 2011, and 2019.

In 2019 an online survey was sent to 392 of the alumnae from 1999 to 2017 for whom the CSMCE had what was believed to be active email addresses. Responses were received from 191 former campers (a 49% response rate). At the time, 28% were still in high school, 47% were undergraduates, 5% were in graduate school, and 20% were no longer in school. Among the responses, 120 (63%) commented on how the camp had made a positive impact on their lives.

“AGAM gave me confidence in my mathematical and problem-solving skills and showed me that not all mathematicians are men. The math club at my high school was composed predominantly of boys, particularly among the highest achievers,” said Carolyn Brown Kramer, Assistant Professor of Practice in the Department of Psychology at UNL who participated in the camp in 1998. “It also expanded my social network in a positive way during the challenging high school years and gave me a sense of independence to be away from home for a week.”

Six responders explained how AGAM launched their interest in an engineering career or major. The exposure AGAM gives to graduate education and to meeting women who have earned master’s and doctoral degrees provides role models to the campers. Twenty-three of the 191 alumnae have either earned a graduate degree—including two PhDs, one MD, and two JDs—or were enrolled in graduate school at the time of the survey.

The program in 1998 inspired one Nebraska student to pursue becoming a secondary mathematics teacher. Jill Edgren, now a math teacher in Wood River, Nebraska, made lasting connections with Nebraska faculty, including Hines, and later earned a master’s degree from UNL and was selected as a Nebraska Noyce Master Teaching Fellow as part of the National Science Foundation’s Robert Noyce Teacher Scholarship Program.

“AGAM truly took me to a four-year undergraduate program, as Dr. Cheryl Miner encouraged me to pursue more than an associate degree,” said Edgren, who went on to become a president of the Nebraska affiliate of NCTM. “I went into math education and saw her promoting the Math in the Middle program, and I felt inspired to apply. Ultimately, I earned a master’s degree. This degree and a repeated experience with Dr. Wendy Hines, since we first met through AGAM, opened the door for me to begin to teach dual-credit courses.”

Of the 118 responders who provided major and minor information, STEM majors and minors collectively make

up 80% of the alumnae. A 2012 camper reported seeing a fellow participant in college, and they still keep in touch occasionally now that they are out of school.

Whether residential or online, fostering tight-knit friendships and preserving a sense of community are high priorities in the program's mission. In fact, 36% of the 191 respondents said they still stay in contact with another participant.

A camper from 2017 described not only the close friendship she made during camp with a group of girls but also how they remained in contact during college visits: "I had a group of myself and four other girls, one of which was my roommate, and we did everything together. We still have group chats on Snapchat and texts that are active, we all have Streaks on Snapchat, and we still comment on every photo someone posts on Instagram. One of my friendships in particular is with [one of the girls from Los Angeles, and I'm from Michigan]. That's a huge distance, yet she still remembered me when she came to Michigan for a college visit. It was very special, and unique, to have that friend from across the country be able to see you again, and I wouldn't have gotten that if it wasn't for this program."

For 2019, the most recent in-person camp, participants mentioned, in an anonymous survey after the camp ended, that the best parts of camp were: being surrounded by people who enjoy math; learning one topic that continued all week, while also being introduced to a new topic each day; making new friends; helping one another out when they had questions; and feeling more connected and less out of place in the mathematical world.

Adapting to an Online Camp in 2020

Today, the benefits of this successful program are sustained with the support of current UNL mathematics Professors Yu Jin and Mikil Foss. As we received applications for the 2020 camp, the nation and world were impacted by the COVID-19 pandemic. The decision was made to refund all registration fees, to offer an automatic acceptance to the 2021 camp, and to provide an online camp to students who were still interested in participating virtually.

One of UNL's graduate students, who would receive her PhD in August 2020, was hired to teach the course. The undergraduate coordinator—a secondary education in science major—with the help of an undergraduate math major, incorporated effective and engaging virtual activities throughout the weeklong schedule that would mitigate the loss of in-person interaction. The campers took part in solving a virtual escape room and participated in online workshops with Lincoln's Duncan Aviation, the University of Nebraska State Museum, and the National Museum of Mathematics in New York City.

Fourteen of the 15 online campers who completed the 2020 evaluation agreed that they felt they belonged during the virtual experience. There was strong agreement that the

woman-focused atmosphere was a valuable aspect of the program.

"Before the camp, I doubted my commitment to math," said a 2020 online camper. "I also didn't really want to pursue math as a major. After the camp, I realized that I do love math and not having a clear, perfect goal right now is OK."

Read more about the online transition AGAM made in 2020 in the December 2020 issue of *AMS Notices* in the Early Career Good Ideas section [1].

After the successful iteration of the camp in a virtual setting in 2020, the program can more easily extend its reach to students globally. One participant in 2020 joined on Zoom from Brazil. In the future, the camp will be offered virtually, until a safe return to traveling and hosting in-person gatherings can occur.

Summary

Twenty-three years after the first camp, AGAM has grown to be a nationally renowned summer program that fosters lasting connections and talented future mathematicians. AGAM has acted as a springboard to give participants the confidence to major or pursue a career in mathematics or another STEM field. Alumnae have gone on to choose careers in a variety of fields, including architecture, engineering, teaching, finance, medicine, and the law. Participants also continue to share with us how they cross paths along their mathematical journeys, using the closed Facebook group for AGAM alumnae and responding to surveys.

Like many mathematicians who have created programs for students at the K–12, undergraduate, or graduate level, the AGAM organizers have learned that it is easier to create than sustain a program. Much of the challenge comes down to finding sufficient resources, including money, faculty, and staff support.

In addition to local support, AGAM has been supported by the National Security Agency (NSA), the MAA (five awards), and the AMS. The AMS has provided AGAM's most consistent support. Starting in 2000, AGAM received 19 awards in 21 years from AMS's Epsilon program averaging \$5,000 per award. Equally important, the renewed AMS support provides evidence of the program receiving national recognition.

More recently, the University of Nebraska Foundation has received donations from the department's alumni as well as AGAM alumnae. The program hopes to develop this into a dependable source of support. The 2020 camp also received support from Nebraska's NSF EPSCoR grant.

The cost per camper of an in-person experience is approximately \$1,200, not including the cost of staff support. In addition to extramural support, the program relies on registration fees. Initially, the registration fee was \$125 for Nebraska students and \$250 for out-of-state students. As costs increased and funding decreased, the program instituted a voluntary, tiered registration fee system where

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a family could choose their registration fee (\$1,000 or \$500 for out-of-state students and \$1,000, \$500, \$350 for Nebraska students) based on the family's ability to pay. To keep the program accessible for low-income students, scholarships are offered to cover the cost of the registration fee as well as travel scholarships for students traveling from outside Nebraska. This support was made possible by the AMS, which in recent years has specified that half of its support should go toward student scholarships, and by a University Foundation donor.

With the addition of virtual events, getting creative in how mathematics is presented to adolescents can benefit how math is perceived and positively influence the lives of young students.

In the words of former AGAM instructor Dr. Katie Johnson, "Play and creativity in math are critical to increase interest in mathematics."

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