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Reflections on Math Students' Circles: Two Personal Stories from Colorado

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Cover Page Footnote
We would like to acknowledge members of the National Association of Math Circles leadership team for providing feedback on this article.

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Synopsis

Math Students' Circles provide an opportunity for mathematicians to work in their communities to engage young students in mathematics as a human, aesthetic, and social endeavor. Sometimes referred to simply as Math Circles, these venues give mathematicians experience in introducing children to topics not typically seen in school curricula in an exciting, hands-on format. This article explores two Math Students' Circles (MSCs) in the state of Colorado from the point of view of two pre-tenure faculty members. One participated in MSCs for four years while working on her Ph.D. in mathematics, the other started an MSC as an offshoot of a successful professional development program for middle school mathematics teachers. We discuss how and why MSCs have influenced our professional lives.

Introduction

Challenging mathematics problems, fun activities, lots of smiles and laughter, and of course, plenty of snacks—these are the makings of a successful Math Students' Circle (MSC). Across the country, new MSCs are cropping up each year, all sharing a central goal of introducing students to topics not typically seen in school curricula in an exciting, hands-on format. MSCs

provide a wonderful opportunity for mathematicians and other mathematics professionals to share their passion for mathematics and to use their strong disciplinary knowledge of mathematics to interact with the youth in their community [9].

This article explores two MSCs in the state of Colorado and how they shaped our professional lives. For each MSC, we describe the history, the basic format, and some sample topics. We conclude with reflections on how and why we became involved, and why we think that MSCs are important. We propose that participating also positively impacts the undergraduate classroom teaching of the involved faculty and graduate students.

Both of us have Ph.D.'s in mathematics and have chosen to dedicate professional time to creating environments that engage children in the depth and beauty of mathematics. We see MSCs as one of the most inviting forums in which to do so.

Background on Math Students' Circles

MSCs have their origins in Eastern Europe, most prominently Russia and Bulgaria, where they have been a part of the mathematical culture for at least 80 years [4]. They were originally called *math circles*, and aimed solely at youth. As there are now also Math Teachers' Circles [1, 2, 3, 10] we refer to them here as Math Students' Circles to make a clear distinction. In the 1980s, these programs began to appear in the United States [4].

MSCs bring mathematics professionals into direct contact with pre-college students in an informal setting. They thereby provide a venue for innovative teaching and discovery of topics outside typical curricula and a community for participants to connect with mathematics. Participation in such programs correlates with improvements in attitude towards, and self-confidence in mathematics. By encouraging students to discover mathematics in a positive environment, MSCs lead to a greater appreciation of the subject and offer avenues for combating the boredom and fear many students associate with the discipline [6].

While the exact count is continually changing, experienced math circle leaders estimate that the United States has 150 MSCs across the country. Bob and Ellen Kaplan's Boston Math Circle, one of the earliest, continues to operate today [4, 5]. In their circle, a professional mathematician poses a

question and allows students to discuss conjectures and follow-up questions organically, with minimal guidance from an instructor. The Kaplans say that encouraging students to struggle and work together on problems creates a sense of curiosity and ownership that leads to confidence [4].

As MSCs develop around the country, the flavor of each varies widely. The Boston Math Circle has an organic culture, while the Berkeley Math Circle has a more structured one [7, 8]. All seek to induce creativity, inspire students, and display the accessibility of mathematics to students of all ages. Exposing more educators to the structure of MSCs may lead to the implementation of more programs, enhancing students' perceptions of mathematics. This paper describes two MSCs that meet in Colorado which have distinct characteristics. Since we each wrote about the MSC we know well, we used first person for these portions of the article.

Summer Math Students' Circle at Colorado State University (Lori Ziegelmeier)

History

The Math Students' Circle at Colorado State University (CSU) began in 2009. That summer, thirteen middle school girls explored mathematical ideas from graph theory, specifically paths and circuits, while simultaneously developing an initial understanding of related elementary proofs. The program continues to evolve to this day, having now served over 250 students of both genders, and involved the participation of over 15 faculty members, 25 mathematics graduate students, and a handful of undergraduate students. Funding has largely come from the Department of Mathematics and the College of Natural Sciences at CSU. Attendees pay a small fee that covers the cost for t-shirts, prizes, snacks, and lunch.

I became involved in this MSC during its second year, while a graduate student at CSU. After the initial organizer, faculty member Dan Rudolph, passed away, I was encouraged to become a co-organizer along with another graduate student. I was immediately hooked and continued to organize the program for four years during my graduate studies.

I believe that our format, choice of topics, and our success at building a sense of community are the crucial pieces of our circle. I now discuss each of these in turn.

Format

After the first summer, the MSC settled into the form of a week-long non-residential summer camp open to boys and girls entering 8th or 9th grade, with a target enrollment of 25 of each gender. We strongly recommend students complete a first course in algebra prior to admission, but deem interest in mathematics to be primary. A typical morning starts with snacks and phases into a mathematical activity, facilitated by either a mathematics faculty member or graduate student. After this initial activity, students break by gender to attend one of two sessions running in parallel. This division will be discussed further in the reflection section. A central feature of each two-hour session is extensive time for in-depth student exploration and collaboration. After a combined lunch, students switch groups, and participate in the other in-depth exploration. At the end of the day, the boys and girls come back together as a larger group for a debriefing and common sharing of ideas, and of course to enjoy more snacks.

On the final day of camp, students stay together. The mathematical activity for this day is often more humanistic; for example, constructing images of each student out of dominoes or having a panel discussing various mathematical careers. Many parents arrive for the closing ceremony, which includes a brief address from the head of the Department of Mathematics or the Dean of the College of Natural Sciences, a slide-show of the students engaging in the activities throughout the week, and finally, a presentation of certificates and t-shirts.

Sample Topics

As this circle developed, we realized that having a central theme and repetition of topics throughout the week greatly enhances the cohesion of the learning experience. These sample themes have included Mathematics through the Ages, Notions of Shape and Space, and Logic, Puzzles and Games.

Within these topics, some of the most engaging and popular sessions include: explorations of straight edge and compass constructions using string and sidewalk chalk, discussing logic in the context of the game *Mastermind*, knot theory using jump ropes, soap films and minimal surfaces, and solving a Rubik's cube using ideas from group theory. The lessons vary with the theme from year to year, drawing on session leaders' interests and areas of expertise.

To keep engagement and enthusiasm high, one of the midweek sessions is a treasure hunt, in which teams of 4–5 students, with the support of a graduate student, hunt for puzzles hidden around campus. After the group has solved the puzzle and demonstrated that each member thoroughly understands the solution, a small clue leads to the next location. All teams end at the location of the hidden treasure, which is often an object that will be used in one of the sessions the following day (*e.g.*, navigational compasses, Rubik's cubes, or protractors).

Community

Developing a sense of community has been a major component of our math circles program. These students spend a week of their summer vacation learning interesting mathematics. If they feel comfortable, they are more likely to collaborate and to view the program, and hence mathematics, positively. We cultivate this sense of community through a wide variety of activities that encourage interaction among participants and the presenters and graduate students. Leaders join students for lunch to connect with the students in a relaxed setting. The lunch formats have included picnics, dining at the dormitory cafeterias, and lunch cards with funds to use as desired in the student center. The other members of the leadership team and I enjoy sitting with students and discussing activities in which they are participating during the summer, their interests, and any questions they may have about mathematics, careers in mathematics, or other topics that may arise. Often, we play an informal, impromptu game of Ultimate Frisbee or capture the flag after lunch with the students. In the downtime, some students continue to think about problems from the day, others play a pattern recognition card game known as SET, or explore with their calculators. Others have in-depth conversations with graduate students about a math topic in which they have an interest.

The CSU MSC has helped to foster a sense of camaraderie among faculty members and graduate students at CSU. From staff to students to faculty, departmental members come together with a sense of purpose to provide the best program possible for the students. It provides a venue to start conversations among individuals who may not otherwise interact within the department. While, of course, the program is intended to engage the student participants, it is just plain fun for all involved.

Reflection

Participating in the planning and implementation of this program for four summers while a mathematics graduate student has impacted me in a variety of ways.

First, it has increased my awareness of the role of gender in an educational context. I have noticed that the boys tend to be more boisterous and vocal while the girls tend to be more hesitant when answering a question or voicing a discovery. The boys tend to be more rowdy and the girls more orderly. Each summer the boys group is typically overflowing, but the girls group has never been completely full. This speaks to the gender inequity in mathematics. I decided to separate the genders during each of the sessions to encourage more female participation and provide targeted attention to the girls group. Separating the boys and girls groups allows the female students to form a close-knit cohort. Unfortunately, my understanding is that many girls form an opinion that they won't or shouldn't like math by the time they are eligible for the MSC. It is important to encourage female students to pursue careers in Science, Technology, Engineering and Mathematics (STEM) fields, and I believe that by involving many female graduate students and faculty members I have made a contribution. The informal conversations we have along the way increase awareness of possible careers and what it is like to go to college and graduate school, and hopefully help students see mathematics as a human endeavor.

Second, I have learned that many students enter the program believing that mathematics is memorizing 100 digits of pi or calculating the answer to a problem as quickly as possible. Thus, I incorporate open-ended questions and emphasize that being able to clearly articulate ideas and logically deduce a result is far more important than any solution itself.

I have also observed the importance of assessing the activities from each year and revising them for future years. At the closing of each day, I would discuss with students what they enjoyed most during the day and what they learned. Through these conversations as well as from my observations each day, I developed a sense of which activities the students found most engaging, as well as which were most educational.

Finally, participating in the planning and implementation of math circles has influenced me on a personal level. Watching students' eyes light up when, after a struggle, they master a challenging concept, observing them find joy

in solving a logic puzzle, and seeing them understand that mathematics truly is accessible are all deeply rewarding. My involvement has also rejuvenated my personal interest in mathematics and led to a sustained commitment to outreach that will persist through the rest of my career.

It is important for the future of our country and our world to engage young people in the beauty and usefulness of mathematics. By participating in outreach activities, youth who may not have previously considered mathematics may discover that it can be both full of wonder as well as a worthwhile pursuit.

Rocky Mountain Math Students' Circle at University of Colorado Denver (Diana White)

History

The Rocky Mountain MSC began as an offshoot of a local Math Teachers' Circle (MTC), a professional development program for middle school math teachers [1, 2, 3, 10]. Together with a middle school teacher and a high school teacher who regularly attended the MTC, I first began a MSC in the fall of 2012. During the first year, approximately 60 students participated, coming from 5 districts. An average of 25 students participated per academic year session, and there were 12 summer participants. Participants were primarily from grades 6-8, though we allowed a few younger siblings to participate as well. The program received funding to start our circle from a Mathematical Association of America Dolciani Enrichment Grant. It continues to receive support from the Mikkelson Education Foundation and the Stranahan Family Foundation, thereby allowing the program to be completely free to students. We had no specific prerequisites of our students, and all came from schools that qualify as high-need.

Like my co-author, I consider our format, choice of topics, and our success at building a sense of community as crucial parts of the circle.

Format

The Rocky Mountain MSC met mid-afternoon one Saturday per month for two hours during the academic year, and concluded with a three-day summer non-residential workshop. Different facilitators led sessions, sometimes one of the three organizers, other times an outside mathematician who was

already part of the math circles community. The program took place in a comfortable setting–a large modern classroom with tables and chairs that were organized to seat four students per group, ample white board space for writing, and a snack area along one side.

Sample Topics

During the academic year, students worked on the mathematical aspects of a variety of different topics including, voting, games, origami, fractals, and geometry. In the middle of each session, we took a break for snacks and informal interactions. During the summer, participants explored the mathematics of the card game of SET, including a three-dimensional variant, and participated in an "Amazing Race"-style adventure across campus. These activities came from diverse areas of mathematics, were accessible to students with distinctly varying mathematics backgrounds, and were designed to encourage hands-on explorations of mathematics and cooperative collaboration from the students.

Community

We built community through ice-breakers and team-building activities, as well as activities where students could interact with each other while exploring mathematics principles. We emphasized cooperative activities over competitive ones.

We handed out snacks and "schwag" (little items like puzzles, or items with the University of Colorado Denver logo on them like a rocket pen), which contributed to keeping the energy level high. During the summer, participants had lunch in the student union one day, choosing from a variety of restaurants in the food court. For many, this was their first exposure to a university campus.

Finally, we recruited students recommended by several teachers participating in the MTC, so groups of students came from the same schools, many of whom already knew either the middle or high school teacher on the leadership team. While we spread them out into different groups at times, I think that this still provided a baseline comfort level from which we could build our community.

Reflection

I conclude this section with some reflection on the impact that the MSC had on me personally and professionally.

Participating in a MSC has had a significant impact on my work as a mathematician who specializes in mathematics education. MTCs for middle-school teachers are a primary focus of my work. Through the MSC, I have gained more hands-on experience working with middle school students, and I frequently use vignettes from these experiences to discuss problems with teachers in the MTCs.

The dedication and enthusiasm of participants also inspires me. Participating students attended up to 25 hours of events. Many had never been on a university campus before, and this provided their first introduction to both the physical space of a campus as well as to a university professor. Several students eagerly inquired throughout the program about what college was like, what careers were available, how to choose a college, what to do in high school to prepare, and so on. Sharing my experiences with them and realizing I might serve to affect how they view their own options for careers and interests felt wonderful.

Finally, working with students has given me an increased sense of commitment to outreach and engagement with the community. I am actively seeking to expand our MSC program, with the hopes of expanding to at least one additional metro location per year. As part of this scale-up effort, I am actively recruiting teachers who have been regular participants in the University of Colorado Denver MTC to lead sessions.

Concluding Discussion

In this article, we have provided first person narratives about two MSCs in Colorado and their impact. We are early-career mathematicians, and we believe strongly in recruiting graduate students and junior faculty for MSCs or other mathematical outreach activities for youth. The opportunity to keep mathematicians active and involved with mathematical outreach to the community throughout their careers represents a chance to instill in many children the notion of mathematics as a human, social, and aesthetic endeavor. We also propose, based on discussions with others in the math circle community, that participating in such outreach programs impacts one's own

classroom in a positive way. In working with youth, we learn to think about how to make mathematics accessible to those with minimal backgrounds, to learn to guide our students to discover mathematics, and to seek new ways to share powerful and important mathematical ideas with them.

MSCs are one forum in which mathematicians and other mathematics professionals can share their passion for mathematics with youth. As members of the academy, we would like to encourage other mathematicians to engage with their local communities by being involved with some form of mathematical outreach. Together, we can work to enhance the public's knowledge and understanding of the discipline of mathematics and to provide our youth with extracurricular mathematical experiences.

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