

Striking the Right Chord: Math Circles Promote (Joyous) Professional Growth



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Abstract Math Circles are extracurricular programs organized by mathematicians, aimed at introducing K-12 students or teachers to novel and interesting mathematics in a collaborative environment. While other authors have discussed the impact of Math Circles on participants, this article explores ways that Math Circles have substantial impact on the professional growth of faculty involved. We hope our experiences and commentary will inspire more faculty to become involved with Math Circles both locally and nationally.

1 Introduction

1.1 *What Is a Math Circle?*

Math Circles are extracurricular programs organized around mathematicians or mathematics enthusiasts collaborating with K-12 students and teachers. The informal atmosphere aims to encourage mathematical exploration and sustained problem solving. Math Circles should be fun, positive, and full of interesting problems. The content typically centers around low-threshold, high-ceiling problems connected to advanced mathematics. Math Circles for students emerged in Eastern Europe in the early twentieth century, and migrated to the USA along with professors that had these experiences in their youth [9]. The Boston, Berkeley, and San Jose Math

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Circles were among the first to appear in the USA during the 1990s. Today, about 200 Math Circle programs exist nationwide [9]. In this paper, we focus on Math Circles led by university or college faculty, so that we may outline some of the impacts on the professional growth of faculty who lead Math Circles.

Math Circles serve a variety of purposes. Goals include creating community, nurturing mathematical curiosity, developing an exploration/research mind-set, offering professional development (for teacher circles), and increasing STEM participation among underrepresented groups. Venues can be on-campus, giving the community greater access to a university or college, or in a school or community building to perhaps lessen the burden of participation. Schedules typically range from weekly to monthly, with Math Teachers' Circles tending to meet approximately monthly, whereas Math Circles for students often meet weekly. In short, Math Circles can be tailored to meet the local needs of those involved, and given such needs, there is likely an existing Math Circle that can serve as a model for creating a new one.

Though many Math Circles started via grassroots efforts, there has been enough sustained interest to lead to the development of national organizational structures. Two major mathematics research institutes, the Mathematical Sciences Research Institute (MSRI) and the American Institute of Mathematics (AIM), developed the National Association of Math Circles (NAMC) and the Math Teachers' Circle Network, respectively. These provide resources and support to the many Math Circles across the country. There is also a special interest group of the Mathematical Association of America dedicated to Math Circles (SIGMAA-MCST). Math Circle sessions and workshops for faculty have become standard fare at conferences such as MathFest and the Joint Mathematics Meetings. Thus, while the title of this subsection is "What is a Math Circle?" it is highly likely that many mathematicians are aware of them. We aim to address some of the ways these Math Circles are impactful, focusing on impact on the leaders rather than participants.

1.2 The Authors: Our Backgrounds and Motivation

Sarah and Lance Bryant are the founding directors of the Shippensburg Area Math Circle for 4th and 5th graders, with about fifteen participants per session and ten Saturday-morning meetings per year. The program started in 2014 as an after-school activity based on a desire to do some math outreach at their daughter's school. The Math Circle has expanded to a district-wide program housed in the Mathematics Department at Shippensburg University. Sarah and Lance were in the first cohort of the NAMC Math Circles Mentorship and Partnership (MC-MAP) program in 2015. They continued to be involved in the MC-MAP program in 2016 as returning Math Circle leaders and again in 2017 as Math Circle mentors.

Diana White runs the Rocky Mountain Math Circle Program, which consists of a regular Math Teachers' Circle, one or more Math Circles for students, a Math Circle Math Camp, and Julia Robinson Mathematics Festivals. The program began in 2010 as a single Math Teachers' Circle, and has expanded over the years

to encompass these broader Math Circle and mathematical outreach experiences. Diana also serves as the Director of the National Association of Math Circles. As previously mentioned, this program of MSRI is designed to nurture the growth of Math Circles by seeding the creation of additional Math Circles in the USA; building a community of Math Circle leaders through which novice and existing leaders would be connected, encouraged, and inspired; providing high-quality resources that help Math Circles build and sustain effective programs; and documenting and disseminating the impact of Math Circle programs across the nation.

Our motivation in this manuscript is to detail some of the many benefits for faculty involved with a Math Circle. We will include our own personal stories, and we invite the reader to reflect on her own experiences or interests in mathematics outreach for connections to these themes. We focus on four areas where Math Circles promote (joyous) professional growth: understanding of teaching and learning mathematics; deepening connections at the department, university, and community levels; broadening leadership skills; and connecting to the larger mathematics community. We hope this inspires more faculty to become involved with Math Circles and sparks deeper research into some of the ideas presented here.

2 Promoting Active Learning

In 2012, one of the five overarching recommendations by the President's Council of Advisors on Science and Technology was to "catalyze widespread adoption of empirically validated teaching practices" [8]. In the wake of numerous studies and reports spanning decades, including a landmark meta-analysis of 225 studies published in the Proceedings of the National Academy of Sciences, having students actively engage with content in their classrooms has been identified as an effective means to increase positive student outcomes [4]. Active learning refers to the teaching practices employed by educators to promote this in-class active engagement. The Conference Board of the Mathematical Sciences (CBMS), an umbrella organization consisting of seventeen professional societies for the mathematical sciences, released a strong statement [1] of support for active learning with this central message:

We call on institutions of higher education, mathematics departments and the mathematics faculty, public policy-makers, and funding agencies to invest time and resources to ensure that effective active learning is incorporated into post-secondary mathematics classrooms.

Despite this near-consensus support for active learning, a Notices article [3] and a six-part American Mathematical Society blog series [2] cited faculty adoption of active-learning strategies as a bottleneck in post-secondary mathematics teaching advancement. We argue that Math Circles provide a great opportunity for faculty to explore active-learning strategies.

Faculty are faced with many potential impediments to implementing active-learning strategies. Class size, grading support, contact time, learning outcomes for courses, student expectations, and instructor experience factor into each faculty

members' decisions on how to structure courses and are at times beyond their control. There are also the pressures that come from fear of failure: if the students do not support the change of course teaching, then teaching evaluations may suffer. This can be especially stressful for pre-tenure faculty. Furthermore, the diversity of faculty environments due to these factors complicates the national dialogue [2]. It can be easy to think that what works at one institution or in one particular setting will not successfully transfer to another. However, we are aware of the support for active learning and have turned to our work with Math Circles to strengthen our development of a more student-centered classroom.

When running a Math Circle or facilitating a session, we find many of the aforementioned limiting factors are easily managed or simply nonexistent (grading, for example). Also, the Math Circle community has promoted a culture of active exploration, collaboration, and inquiry as hallmarks of successful sessions. Thus Math Circle leaders become immersed in the process of leading engaging sessions that involve and inspire all participants. Removing lecture, homework, exams, textbooks, and other common course components from the learning environment can be freeing but we have also found it to be intimidating. Thus Math Circles provide a space for faculty to practice a variety of active-learning strategies without fear of adverse repercussions, thereby allowing them to both build their skills and confidence.

For a typical mathematics course, structure and learning goals are centered around content, and problem-solving strategies must be inserted into this structure. Our work in Math Circles has allowed us to create (or borrow) lessons that are designed the other way around: start with problem-solving techniques and use mathematical settings to illustrate their uses, then present students with challenges from a variety of topics. What is gained from these sessions are authentic experiences for how problems are approached and solved in mathematics, making it easier to incorporate these ideas into more traditional classroom settings. Some of the materials from our Math Circle that we have used in college classrooms include puzzles designed to introduce approaches for problem-solving (e.g., “try an easier problem” or “work backwards”). These are particularly good prompts for introduction to proofs courses, where students must break out of procedural and algorithmic practices to explore the creative side of problem-solving. We have also drawn on the work of Joshua Zucker, a well-known Math Teachers' Circle leader, whose article “Be Less Helpful” addresses the nature of stepping out of the lecturing spotlight and allowing students to embrace the full experience of learning, including the struggle [10].

3 Connections Between Faculty, University, and Community

Mathematical outreach programs, and Math Circles in particular, lie at the intersection of the interests of universities, local communities, public policy-makers, and the mathematical community. Thus there is much potential for substantial connections

between these stakeholders. However, when Math Circles are viewed as community service, they are often not valued as highly as scholarly research and only incidental to teaching in higher education. In “Making the Case for Professional Service,” Ernest Lynton establishes a working definition of professional service, taking it to be work based on professional expertise. Lynton claims “professional service can and should be an important element in the definition of faculty roles and rewards—not only because of its societal and institutional benefits. It also can constitute scholarship of the highest order, equivalent in intellectual challenge, creativity, and importance to scholarly research and scholarly teaching” [6]. We absolutely agree. Math Circles are an exemplar of professional service in mathematics.

Math Circles satisfy Lynton’s definition of professional service because they are outreach programs that rely heavily on the mathematical expertise of session leaders. As session leaders we must draw on our deep understanding of a wide range of mathematical ideas. We must understand entry points for these big ideas and be comfortable with deviations from the expected path of exploration. While it is often challenging (and keeps us on our toes!), there is nothing about leading a Math Circle that relies on rote knowledge or repetition. We draw on our expertise in crafting and leading these sessions in a way that represents a deep connection to the content and to the learners.

When arriving in a new town, faculty members may not be aware of existing tensions or bonds between the university and local community. In our personal experiences, there has been some positive and some negative aspects of the “town-gown” relationships. Thankfully, we have found that our towns are excited about the opportunity of having a Math Circle and the university appreciates the valuable link to the community. By inviting students and their families into the university, a Math Circle can literally open doors to the institution and show a commitment to the younger learners or teachers in the area. Some Math Circles travel to the local schools or libraries, again with the goal of breaking down barriers of access and bringing faculty expertise to non-university spaces. We have found that our professional and personal networks in the local community are also enriched by this work.

What we have found to be one consistent source of joy in working with Math Circles is the satisfaction of making strong connections with young learners, many of whom have never met a “mathematician” before. All three authors are first-generation college students and did not grow up knowing that people still worked on mathematics problems long past high school. We did not know that some mathematics problems look like puzzles or that sometimes some mathematics problems remain unsolved. It is all too common to hear people describe mathematics as completely objective, absolutely black and white, with knowing the right answer as the only currency of mathematics. Participants in a Math Circle not only meet mathematicians, but also they become them. They get to see the “play” behind real mathematics and appreciate that an answer is almost never as valuable to a good mathematics conversation as a question is. In turn, Math Circle leaders can learn from the participants some excellent strategies for being fearless, for asking “silly” questions, and for being honest when something is not fun or seems impossible.

4 Broadening Leadership Skills

Running a Math Circle means wearing many hats, including some that mathematics faculty seldom get to wear. One must connect with the community of interest, generally needing to make personal contact with teachers, community centers, or other organizations that can help with advertising the program to the target audience. There is a need for applications, flyers, and ideally at least a basic website. Mathematics faculty may or may not have skills for these various things. Often, they collaborate with others to accomplish them, and thus need to find volunteers and build relationships. In addition, as Math Circle leaders we have had to learn the ins and outs of hiring and training students, managing grant paperwork, submitting reports, and responding to press requests. All of these skills have prepared us to consider larger projects and for working with constituencies across our institutions and in our communities.

A large-scale program can involve dozens up to hundreds of K-12 participants, undergraduate and graduate student helpers, and a variety of faculty facilitators. The collaborative nature of Math Circles lends themselves naturally to partnerships between higher education institutions, K-12 schools, and business sponsors. For example, the Maize and Blue Math Circle in Michigan has partnered with Ford and DTE Energy Solution to support a free middle school Math Circle at the Dearborn STEM School. Learning how to build and manage these types of partnerships is a valuable skill for faculty seeking future leadership roles.

5 Connections and Identity in the Mathematics Community

Coming out of graduate school, a new faculty member is a part of a community built around an area of expertise. Over the years, new sub-communities are joined. Perhaps the faculty member is in the MAA's Project NExT program or joins a new faculty cohort at her hiring institution. What we have found unique about the Math Circle community is its ability to be vertical in nature, uniting K-12 students, teachers, undergraduate students, graduate students, mathematicians, and mathematically inclined parents or volunteers. Thus the Math Circle community in mathematics has far reach and interest in a variety of areas, not just to a sub-specialty of research.

The Math Circle community also functions with a refreshing lack of concern over tenure-track status or job titles. People from all sorts of backgrounds work with Math Circles, so there is great diversity among those involved, including long-term temporary faculty, industry professionals, government employees, and freelance or independent contractors. In fact, if you happen upon a group of Math Circle leaders at a conference or workshop, we recommend skipping the usual opener "Where are you at?" and opting instead for "Do you know the Math Circle Salute?" If you don't know it, watch James Tanton's video [7] or, better yet, help out at a Math Circle for a

day and learn it! This fun bit of the Math Circle community hints at the playfulness of those involved; after all, it's hard to take yourself too seriously when your arms are twisted in knots in front of near strangers.

6 Our Stories: A Few Personal Notes on Math Circle Involvement

6.1 Sarah

My mathematical role models are those who have not only increased mathematical understanding but also contributed to broadening participation in mathematics. Whether through a Math Circle or some other activity that takes an authentic approach to exploring mathematics, the words of Francis Su can inspire us all: “The goal of broadly getting people to appreciate math is not at odds with bringing more people into deep mathematics. Connect with people in a deep way and you’re going to draw more people into mathematics” [5]. Yes, this includes (in the case of our Math Circle) 4th and 5th graders. I am dedicated to increasing access and improving equity in mathematics, and being involved in Math Circles has helped enrich this part of my personal and professional mission. There have been other benefits as well, as I have been empowered to explore new lines of scholarly work and expand my mathematical network, thanks to my involvement in Math Circles.

6.2 Lance

Like other faculty members I have known, I became more interested in K-12 education as my daughter started elementary school. In 2014, when Sarah and I worked with the director of our daughter’s school to start an extracurricular math program, we envisioned a small program running for a few years. I did not expect the overwhelming response from the community, for sessions to consistently have over fifteen participants, and I certainly did not expect to be working with Math Circle leaders across the country. I have seen first-hand how a Math Circle program can easily gain momentum and bring someone into a vibrant community of mathematicians.

My department has run an annual math event for high school students since the late 1950s. When I became director in 2010, the main event was a quiz bowl. After attending the Math Circles Mentorship and Partnership (MC-MAP) grant workshop in 2015 and participating in a Julia Robinson Math Festival (JRMF), I saw a better way to generate excitement about mathematics among the high school student and their teachers, while at the same time providing opportunities for our undergraduate students and faculty. I replaced the quiz bowl with a JRMF. We now hold several

problem-solving sessions each year for our undergraduate students both for their own benefit and to prepare them to be table leaders for the JRMF and our Math Circle. Our faculty enjoy working on these problems as well, and I feel like my work with Math Circles has built connections across my campus that I would not have otherwise. So, in addition gaining new relationships to those in the Math Circle community, this work has added to many previous relationships with colleagues as well.

6.3 Diana

Being a Math Circle leader has affected every aspect of my career. In particular I credit almost all of the facilitation techniques that I use in my upper-level undergraduate mathematics classes to my work with Math Teachers' Circles. One of the initial leadership team members for my Math Teachers' Circle was a high-school mathematics teacher with extensive professional development expertise. Our collaboration resulted in me having the opportunity to observe and then practice implementing a wide variety of active-learning and group facilitation techniques with teachers. With feedback from this expert high-school teacher, my facilitation skills improved tremendously, and I proceeded to also implement them in my undergraduate mathematics classes. In addition, I also used these techniques (and more) in leading professional development workshops with other mathematics faculty.

7 Conclusion

Mathematicians deserve a chance to play, to grow as teachers without the inherent pressures of the evaluation system, to try new types of math problems outside their expertise, and to nurture new friendships and connections through projects they are passionate about. We have found Math Circles to be the perfect outlet for these areas of growth, giving us the opportunity to refine our professional skills in a fun and joyful environment. We encourage other faculty and math enthusiasts to consider starting or joining a Math Circle, not just because of all you will be giving to others involved, but also for all you will be receiving in turn.

We hope this manuscript serves as a call for more faculty to consider the ways that being involved in Math Circles is beneficial for them and very rewarding. We would also expect that our personal stories are common in the larger Math Circles community, a topic certainly worthy of continued research.

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