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BOARD # 237: Exploring the Impact of Community Engagement on Undergraduates via Math Circles for K–12 Students: An NSF-IUSE Project

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Background

Math circles are informal enrichment programs in which K–12 students work together to solve engaging math problems [1]. In this work, we report on the math circles conducted by undergraduates at Stevens Institute of Technology as part of their enrollment in a credit-bearing community engagement course. The study participants span two cohorts of undergraduate Math Circle Leaders (MCLs) from Fall 2023 (N=9) and Fall 2024 (N=10). MCLs generally worked in pairs, conducting math circles at various community partner sites in Hoboken, NJ, including elementary schools, a charter school, the public library, and the Boys and Girls Club. The course is open to all STEM undergraduates, and while most MCLs have been math majors, some have joined from other disciplines, such as biomedical and computer engineering. We posed the following two research questions (RQs): (1) How do MCLs view the role of math in society? (2) What skills do MCLs view as transferable to their future goals?

Methods

The primary data source for answering RQs 1 and 2 was an end-of-semester interview with each MCL. The interview protocol was designed to elicit details about the MCLs' teaching approaches, notable moments with the math circle participants, and dynamics of their partnership (where applicable). The final interview questions most pertinent to this study were as follows:

1. What skills do you feel you've gained through your experiences as a Math Circle Leader?
2. Could you apply these new skills to your future career? If so, how?
3. What role do you think math plays in society?

Interview data underwent multiple rounds of inductive coding, following an In Vivo methodology as a first round [2]. One author (ELA) undertook this initial round of coding for three of the interviews. The other two authors (JC and AN) used the initial codebook to analyze the same three interviews, adding and modifying codes as they saw fit. A consensus approach to interrater reliability was used and the process was repeated for an additional two interviews. After a second consensus was achieved, the remainder of the interviews were coded. This research was approved by the university's Institutional Review Board (IRB #2023-022).

Results

RQ1. Perceived Role of Math in Society

A key tenet of community engagement is the use of one party's knowledge to address real-world challenges. All nineteen MCLs were asked to describe the role of math in our society from their perspective. We hypothesized that this interview question could provide insight into how the MCLs connect their math knowledge to the world around them, including their beliefs about the utility of math beyond a classroom or their future careers. As role models, MCLs' attitudes and beliefs about math have the potential to influence those of the children they interact with in the math circles, shaping how they perceive and value the subject. Their responses to this question were characterized as described below.

Ubiquity and Utility. All but two of the MCLs (Chandra and Harrison) spoke about the omnipresence and power of math, in that it is a broad, multi-faceted discipline, that it underlies many other fields and real-world processes, and/or that it is simply ubiquitous (i.e., "Math is everywhere!"). These responses largely included the application of math, with examples spanning from its use in payroll, to trip planning, to the creation of the mp3 filetype.

Several of those 17 explicitly stated that math was necessary to function in society or to understand how the world operates (N=7). Others described math as a way of thinking, such as a guiding philosophy for making arguments and decisions (N=7):

> *I think being trained in math from a young age just makes people better thinkers. It makes people more analytical thinkers. It allows you to follow a process. I also think the overlaps into logic help people better understand how to navigate an argument, like how to find a truth in something.* [Karsten]

The two outliers in this category were Chandra and Harrison. Chandra spoke about math in relation to her philosophy on life, but her explanation highlighted an interesting nuance. While the others, such as Karsten (above) spoke of math as an underpinning, Chandra integrated math into her pre-existing philosophy, using it as an explanatory tool instead:

> *I think to me, I have always viewed the world as something easy to just get through because everything has a solution…and math is a concept that reinforces that.* [Chandra]

On the other hand, Harrison provided an entirely different response to this question. While he acknowledged the applications of math, he argued that the most important role of math in society is actually its fundamental existence:

> *I think its most fundamental role is as a hobby or as something of interest to people. It plays a role as something for people to explore and have fun with…I was never particularly interested as to why what I was doing was useful.* [Harrison]

Like Chandra (and others), Harrison paints a clear connection between his view of math's societal role and his own beliefs and experience.

Math as a Polarizing Topic. Several of the MCLs used this question to speak about others' perceptions of math. In particular, MCLs felt that people were either unaware of the vastness or utility of math, or that many harbor negative feelings about it (N=7). Four of them related these feelings specifically to what they view to be an inadequate or counterproductive means of teaching math at younger ages. Some, like Jade, recounted their experiences as K–12 students, discussing how their appreciation of math did not emerge until they were able to see its applicability.

> *Senior year [of high school] I had my calculus class and in that class everything just clicked…Like, beforehand it was just like I was just doing [math] 'cause they told me to do it, but l was like, 'Oh, it has actual applications to real life. This is interesting.' And so*

> *I feel like the fact that when we're learning math at a lower level, we never really know why it's useful.* [Jade]

Caveats. Interestingly, two MCLs did provide caveats to their responses, contrasting with the others. Blake was one of the 17 MCLs who touted the ubiquity of math, referring to it as a foundation to all other disciplines. He also felt strongly that it was critical for logic and argumentation, jokingly asking the interviewer a rhetorical question: "*Don't you think the world would be better if everybody you ever argued with understood a mathematical proof?*" However, he qualified his statements by saying that this could not be applied to what he called "abstract concepts:"

> *The only thing it doesn't apply to is justifying abstract concepts. 'Cause you can't use two plus two to justify that, like, I don't know, like something is wrong with the war in the Middle East.* [Blake]

Another MCL, Flora, lauded the utility of math at all levels of everyday life, giving the example of buying a cup of coffee and the math involved from calculating the amount of change received, to the finances of the business and even the economy. However, like Blake, she spoke of the limitations of math, and particularly the false notion that it is immune to bias:

> *People who are creating [computer] programs that use math kind of hide behind the guise of 'Oh, it's numbers, so it's a fact' when [they] have biases in their day-to-day life too... So it may not be as unbiased as it may seem.* [Flora]

RQ2. Development of Transferable Skills

For RQ2, MCLs were asked to identify the knowledge or skills they felt they acquired or honed as a result of their experiences in the program, as well as the extent to which - if at all - those takeaways would serve them in their future careers. All 19 MCLs were able to identify at least one skill they gained from the program, with most naming two or more. Their responses were coded and classified among five emergent categories (Figure 1). The two most commonly-cited categories, *knowledge-sharing* and *empathy and openness* are described in greater detail below.

Knowledge-Sharing. Twelve MCLs identified knowledge or skills that we classified as knowledge-sharing. This was distinct from other responses that described general communication skills (i.e., **Interpersonal**, Figure 1) in that knowledge-sharing implies an understanding of the other person or of how people learn, and tailoring your communication accordingly. For example, the largest code in this category was *Distilling Knowledge*, or the ability to convey information in more understandable terms. Multiple MCLs, such as Kaye, acknowledged the difficulties they initially faced in refraining from math jargon. However, this afforded her the opportunity for growth:

> *I think being able to explain a concept in kids' terms is coming a lot more naturally to me, 'cause before I was really struggling to not mention the mathematical terms, like 'function,' 'variable'...the kids themselves would really help me with that, 'cause they would say like, 'oh, it's input, output,' [so] I would roll with that.* [Kaye]

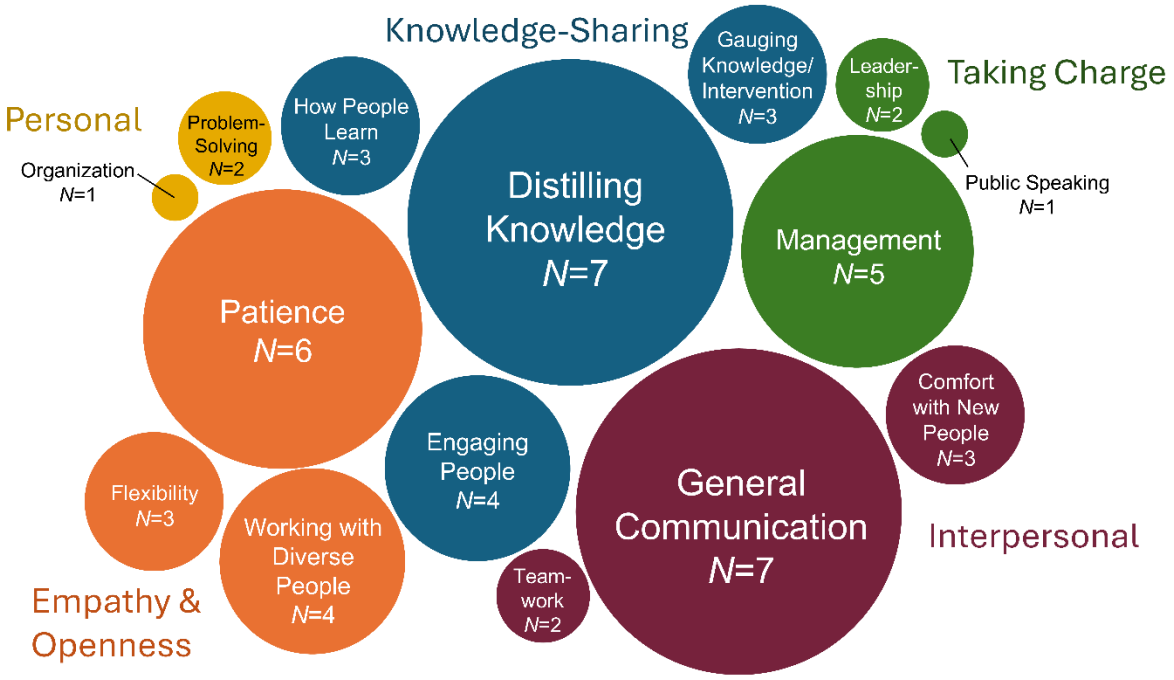

Figure 1. Classification of the knowledge and skills identified by the MCLs.

Other skills in this category included knowing how to engage their particular students, as well as what Hazel described as gaining an "intuition" for knowing when to intervene:

> *I think letting them do their thing for a bit, not jumping in and correcting them immediately, but…just like the intuition of when a student is struggling too much, versus like to where it's beneficial to them still. I would say that is probably the biggest skill that I took away is just knowing when that time is.* [Hazel]

Empathy and Openness. Ten MCLs discussed the ways in which the program fostered a greater appreciation for working with students of varying math skills, linguistic differences, and disabilities, as well as increased flexibility and patience overall:

> *Maybe a little bit of patience, just kind of not being like, 'Okay, let's get to the answer.' Like, learning to slow down and realizing that like the process is the important part…So trying to slow down and make sure they understand what they're doing and why they're doing it the way they're doing it.* [Flora]

Career Applicability. Each MCL was asked to describe their future career plans, and whether or not they could envision putting their aforementioned skills to use in that context. It is worth noting that Stevens Institute of Technology does not offer degrees or coursework in education, and that the majority of the MCLs, save for Blake and Jonah, did not intend to pursue a K–12 teaching career. They described - with varying degrees of certainty - future careers in finance, software engineering, law, data science, and more. Still, 18 of the 19 MCLs replied affirmatively to this question, with the 19th MCL instead discussing the relevance to their current tutoring job

and everyday life. For the rest, their responses included the value in being patient, knowledge of how to lead or manage others, and, most commonly, how to distill knowledge to their future colleagues:

> *In any relatively high-level area, the person that often you're explaining this to, they don't want to know all the nitty gritty details. They don't want to know everything that goes behind the model…So being able to explain concisely, informatively, and in a way that makes sense to someone with a different background than you, is a very, very important thing to have in a professional setting.* [Graham]

Conclusions

In this study, MCLs described their views of the pervasiveness and primacy of math in the real world, from its modern-day utility to its use as a guiding philosophy. Notably, some MCLs, such as Jade, experienced a shift towards a math-positive perspective relatively late in her schooling, and only after learning of its applications. Because of this, it is our hope that the MCLs are able to share this knowledge with the children in their math circles and serve as a math-positive influence for them. Furthermore, all of the MCLs reported positive takeaways from their experiences in the program. Given that most studies on community engagement tend to focus on the population on the receiving end, these results are encouraging and support the use of community engagement as a viable learning experience for undergraduate STEM students, regardless of their future career goals.

Future Directions

We will continue to analyze data collected from the 2024 interviews, as well as the MCLs' reflections and observations in order to understand other ways in which the MCLs' participation in the program impacted them.

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