The Better Math Teaching Network

Year One: Developmental Evaluation Report

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The Better Math Teaching Network (BMTN) is looking to transform high school math instruction in New England and beyond. Through this network, researchers and practitioners are working together to make high school Algebra I classes more student centered. Launched in 2016 by researchers and expert practitioners at the American Institutes for Research (AIR), with support from the Nellie Mae Education Foundation, the network is grounded in the following FIVE CORE PRINCIPLES:[1]

1. **Teachers are central to change.**
   Teachers shape students' learning experiences and beliefs about math. It is possible to create classrooms that are more strongly student centered—classrooms in which all students are actively and meaningfully engaged in learning math.

2. **Student-centered teaching is complex and almost impossible to do in isolation.**
   Teaching to maximize student engagement and understanding is complex. One way to deal with this complexity is for teachers to participate in structured, collaborative learning with other teachers and researchers.

3. **Teaching can be continuously improved.**
   Teaching is a craft to continuously hone. Teachers use practices daily that lend themselves to ongoing, incremental improvement. Continuous improvement methods from industry and healthcare hold promise for education.

4. **Quick-cycle improvement methods provide opportunities to study and improve teaching.**
   Many of the practices teachers want to improve can be studied with quick-cycle research and development methods. Teachers can test and refine strategies within and across lessons, realizing improvements every few weeks, rather than waiting until summer break.

5. **Research and practice should be seamlessly integrated.**
   Too often, research and practice fail to inform each other. Our network includes researchers and practitioners working arm-in-arm to test and refine improvement strategies in real classroom settings. Mutual respect fuels our work.

1 http://www.bettermathteachingnetwork.org/

During the 2016–17 school year, 23 teachers from five New England states[2] participated in the first official year of the network's operation. Teachers were selected from a pool of volunteers who applied to be part of the initiative. Participating teachers work in urban, suburban, and rural contexts and teach at least one Algebra I course to 9th-grade students[3]. Teachers committed to work collaboratively to make their teaching more student centered using the improvement science approach. The BMTN is organized as a networked improvement community, which is a structured network of researchers and practitioners working together to address a common problem of practice—in this case, student engagement in mathematics.

Student Engagement in Algebra 1

Far too many American students are disengaged in learning mathematics (Boaler, 2002). Student engagement in Algebra I is a particularly pressing problem of educational practice due to the importance of the course in students' academic trajectories. While Algebra I was once considered an advanced high school math class (Schiller & Hunt, 2011), more middle school students are now enrolled in Algebra I. This shift has been driven by research that shows how early access to algebra is associated with students completing higher-level math courses in high school, which in turn predicts high school graduation and student postsecondary success (Stein, Kaufman, Sherman & Hillen, 2011). A 2006 study of high school students in Florida found that students who failed Algebra I were four times more likely to drop out than students who passed the course (Orihuela, 2006). Successful access to algebra content is an equity issue because lower income and lower achieving students tend to be tracked into lower trajectory math courses, which amplifies achievement gaps in high school (Gamoran, Porter, Smithson & White, 1997; Stein, et al., 2011).

"The Better Math Teaching Network aimed to harness the problem solving power of networks in pursuit of more student-centered teaching and learning."

Deeply Engaging Students in Algebra

Student-centered learning is at the core of the work of the Nellie Mae Education Foundation. In their framework for student-centered education, they present four tenets of student-centered approaches to learning: learning is personalized; learning is competency based; learning takes place anytime, anywhere; and students exert ownership over their learning. The foundation theorizes that these tenets provide deeper learning for students which results in students building the knowledge, skills, and dispositions to succeed in college, career, and civic life *(Putting Students at the Center: A Reference Guide)*.

In 2014, the American Institutes of Research conducted a study, with support from the Nellie Mae Education Foundation, called *An Up-Close Look at Student-Centered Math Teaching: A Study of Highly Regarded High School Teachers and Their Students.* Through case studies of highly regarded high school mathematics teachers, this study sought to break down the concept of student-centered learning *in mathematics* into key features. AIR researchers found that teachers enacted student-centered learning in different ways, but key common practices included allowing for heavy student contribution, encouraging active student exploration, using problems that require students to think critically and communicate their thinking, and asking students to explain the "why" of their answers.

2 One teacher was from West Virginia.

3 Occasionally teaching assignments change, and in one case a pilot teacher had no Algebra I sections in 2016–17.

Drawing on this study and prior research, leaders of the Better Math Teaching Network refined their stance on student-centered mathematics learning to focus on **three principles for deep engagement in algebra (DEAs):**

Connect: Make connections among mathematical procedures, concepts, and application to real-world contexts, where appropriate.

Justify: Communicate and justify mathematical thinking as well as critique the reasoning of others.

Solve: Make sense of and solve challenging problems that extend beyond rote application of procedures.

These three DEAs frame the improvement cycles that teachers in the network design and implement.

Learning How to Deeply Engage Students in Mathematics Through Networked Improvement Communities

The NIC concept

The BMTN is organized as a network improvement community, or NIC for short. NICs bring together practitioners, educational leaders, and researchers to solve a pressing problem of practice (Bryk, Gomez, Grunow & LeMahieu, 2015; Hannan, Russell, Park & Takahashi, 2015). In promoting the use of improvement science in networked communities, Tony Bryk and colleagues at the Carnegie Foundation for the Advancement of Teaching have recently promoted the NIC concept as a way for practitioners to learn how to improve education at scale by building an evidence base about both productive practices and knowledge of implementation processes to address persistent problems of practice and policy (Bryk et al., 2013). NICs are professional learning communities distinguished by **four essential characteristics:**

1. They are focused on a well-specified common aim.
2. They are guided by a deep understanding of the problem, the system that produces it, and a shared working theory of how to improve it.
3. Their work is disciplined by the rigor of improvement research.
4. They are coordinated to accelerate the development, testing and refinement of interventions; their rapid diffusion out into the field; and their effective integration into varied educational contexts (Bryk et al., 2015; Russell, et al., 2017).

Improvement science (including quick overview of PDSA cycles)

Improvement science is an applied science that has dramatically improved practice in a number of industries by helping practitioners learn their way into improvement. The approach has a long history in the manufacturing industry and subsequently the healthcare field, and provides a disciplined methodology for learning from practice to improve the systems and processes that shape work within organizations (Berwick, 2008; Deming, 2000; Gawande, 2007; Langley et al., 2009). More recently, education reformers and leaders have looked to improvement science as a way to accelerate large-scale improvement in schools and districts (Lewis, 2015). The teachers in BMTN use improvement science methods to improve their math teaching.

Improvement science methods provide a disciplined approach for practitioners to learn how to improve work processes by introducing small changes (Bryk et al., 2015; Bryk, Gomez, & Grunow, 2010; Deming, 2000; Langley et al., 2009; Lewis, 2015; Taylor et al., 2013). One central tool of the improvement science approach is the PDSA cycle. The PDSA cycle is an inquiry routine involving four steps: Plan-Do-Study-Act. The logic of the cycle is that practitioners learn how to improve their practice by planning a specific change tied to a working theory of improvement, test the change,

study evidence to assess whether the change constituted an improvement, and decide what action to take in light of what was learned. Identifying hypotheses, testing those hypotheses, and comparing results with one's predictions generates new details about how to improve practice. This rapid inquiry generates new learning and allows the opportunity to examine variations in context that support or constrain the practice. BMTN teachers use the PDSA cycle routine to test instructional changes and to see whether they improve student engagement in algebra.

The power of networks

Bryk and colleagues (2015) have theorized about how networked improvement communities can provide an organizational structure that helps practitioners learn to use improvement science to develop and test better work processes and learn from each other as tested innovations spread throughout the network. Across fields, networks have been looked to as a way to organize people to solve problems that require the integration of knowledge distributed across organizations and mobilize diverse social actors to engage in collective action (Kapucu, Hu & Khosa, 2014; Powell, Koput & Smith-Doerr, 1996). Networks are seen as a way to take advantage of a broad set of resources and increase innovation, learning, and capacity building for problem-solving (Brass, Galaskiewicz, Greve & Tsai, 2004; Issett, Mergel, LeRoux, Mischen, & Rethemeyer, 2011; Kenis & Provan, 2009; Klijn, Edelenbos & Steijn, 2010; Weber & Khademian, 2008). Networks can also facilitate the spread and implementation of promising solutions (Greenhalgh, Robert, Macfarlane, Bate & Kyriakidou, 2004; Valente, 1995). The Better Math Teaching Network aims to harness the problem-solving power of networks in pursuit of more student-centered teaching and learning.

History of the Better Math Teaching Network

The Nellie Mae Education Foundation is currently funding the Better Math Teaching Network, a networked improvement community aimed at advancing the Foundation's work to build an evidence base and the practical capacity to expand student-centered teaching and learning in New England. The American Institutes for Research received funding in 2014 to launch and operate a NIC focused on student-centered learning in high school Algebra I as a potential solution to the problem of high rates of high school math students disengaged in mathematics learning. Network leaders from AIR spent roughly a year preparing to launch the network, working with the Carnegie Foundation for the Advancement of Teaching to learn about improvement science and the networked improvement community concept. In tandem, network leaders piloted some of their ideas for building a network with a group of nine teachers during the 2015–16 school year. During this time, the network also developed a working theory of improvement, and made the decision to focus on one component of that theory: making classroom instruction more engaging for students.

The network launched officially in the 2016–17 school year with 23 teachers. The network held four face-to-face full-network meetings. Between meetings, network leaders supported teachers' efforts to identify and test changes in their practice that promote deeper engagement in algebra content. During this first year of network operation, the participating teachers worked hard to learn and enact the improvement science approach. Their work was captured in a booklet that summarized their small tests of change and what they learned about student-centered learning in Algebra I. The network is currently in its second full year of operation and has expanded to work with 43 teachers representing all six New England states.

BMTN is an important example of the use of the networked improvement community concept in education because it is trying to improve classroom instruction in Algebra I, a course that is a crucial milestone in students' academic trajectories. Though the networked improvement community concept is rapidly proliferating the education field, many NICs have not tried to address classroom instruction. Given the critical role of classroom instruction in improving student learning outcomes, the BMTN's focus on teacher practice is an important case for both improvement science and school improvement approaches.

Recognizing both the promise and challenges of networked improvement communities to support student-centered teaching and learning, the Nellie Mae Education Foundation invested in an intensive developmental evaluation process exploring the network's development, outcomes, and dissemination of lessons learned. This developmental evaluation process aimed to provide timely and actionable information to network leaders and members, accelerating their capacity to meet their aim. Additionally, the developmental evaluation strives to produce useable knowledge for the education field and specifically other educators, policymakers and researchers utilizing the NIC model to organize for improvement and address high leverage practical problems.

Report Overview

This report outlines findings from the first year of this developmental evaluation of the Better Math Teaching Network. Our aim was to provide a descriptive and analytic portrait of the network's first year of operation. We drew on a range of data sources to examine this networked improvement community in action, including:

- Observations of whole- and small-group network meetings,
- Interviews with participating teachers conducted at multiple time points throughout the year,
- Teachers' responses to a survey designed to measure teachers' experiences with key features of the NIC concept,
- Analysis of teachers' formal and informal connections to one another that are facilitated by the network,
- Documentation teachers generate through their improvement cycles,
- Classroom observations and follow-up interviews with a small sample of teachers.

Further information about our inquiry approach is available in Appendix A.

We present our findings in two ways. First, we present three in-depth case studies that describe how teachers with different motivations, experiences, and local contexts benefited from participation in the network. Then we present chart essays, which describe key themes that emerged from our analyses, focused as follows:

- Teacher participation in the network
- Teacher understanding and use of the improvement science methodology
- How local context shapes teacher engagement in the network
- How teachers believe their work in the network is influencing their teaching
- How teachers believe their work in the network is influencing their students

We present our findings in two ways. First, we present three in-depth case studies that describe how teachers with different motivations, experiences, and local contexts benefited from participation in the network. Then we present six chapters, which describe key themes that emerged from our analyses, focused as follows:

- Teacher participation in the network
- Teacher understanding and use of the improvement science methodology
- How local context shapes teacher engagement in the network
- How teachers believe their work in the network is influencing their teaching
- How teachers believe their work in the network is influencing their students
- How the network is laying the groundwork for spread and scale

These chapters were written so they could be read either individually or as a set, depending on the interests of the reader.

We believe our findings have implications for educators and education leaders who are interested in promoting student-centered mathematics teaching and learning. The case studies illustrate how a diverse set of teachers utilized support from the network to pursue more student-centered instruction, and the chapters speak to how participation in the network provided structure and resources for teachers to make changes that they perceive to be influencing their teaching and their students' engagement in mathematics.

Additionally, educators and building or system leaders interested in the networked improvement community concept for organizing for practical improvement can see a portrait of how this network is organized and operated to support educator learning and teaching in more student-centered ways. The chapters on participation and improvement science reveal how network leaders designed structures and supports for teachers to take up this approach to improvement and learn from one another. The findings related to spread and scale spotlight how the NIC is trying to generate insights about student-centered learning that can be shared with educators within and beyond the network.

Case Study Overview

Networked improvement communities and improvement science recognize, by design, the adaptive nature of educators' efforts to grow their practice and improve student outcomes. These models overcome some of the key limitations of other education reform models in that they assume and are structured for the sense making and adaptation that must occur for new approaches and tools to be used well across variations in teachers, students, and policy contexts. Given this, we thought it important to design a significant portion of the evaluation to examine how the work was unfolding within teachers' own contexts. We employed a case study approach of the Better Math Teaching Network during the 2016–17 school year so that we might observe and understand the lived experience of network participants in the contexts of their schools and classrooms.

The case studies provide a robust view of how teachers engaged in the network: how they collaborated, how it changed their thinking and teaching practice, what they learned, what challenges they faced and how the network helped solve those problems, the role individual teachers played in the network, the role the network played for teachers, and their vision for the network. We thank our case study teachers, and their school leadership, for so generously inviting us into their schools and into their practice in order to share these stories.

Case 1: Collaboration and Spread in Rural Maine

This is the case of two teachers who—with school leadership support—fully embraced and leveraged the supports of the Better Math Teaching Network and optimized their collaboration to bring previously unavailable resources to their rural community and spread the ideas within their school.

Case 2: Network as a Critical Learning Support

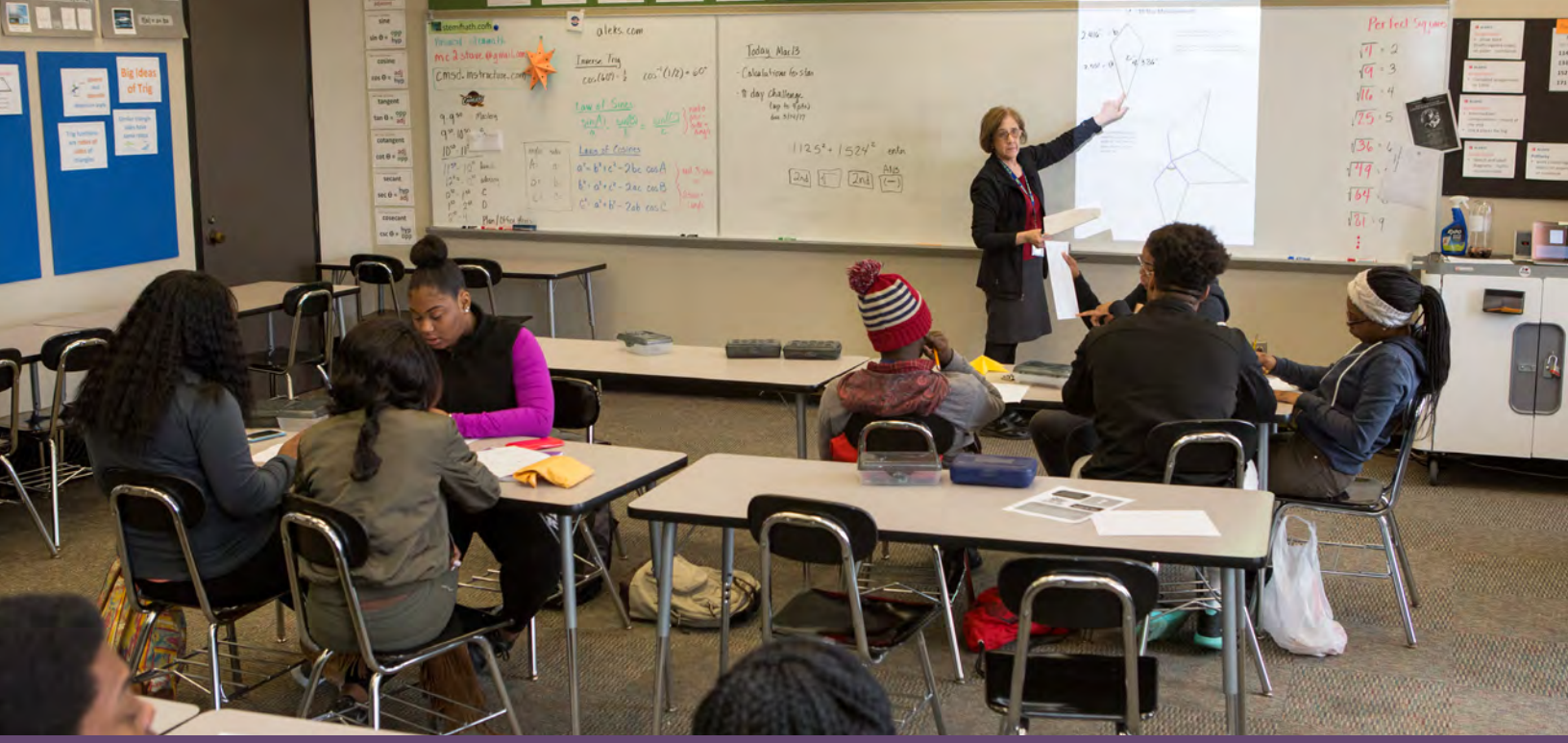
This is the case of two early to mid-career teachers who were ready to change their practice. Highly motivated to make difficult changes, these teachers needed professional coaching and collaboration beyond what their schools currently provided. This is a case of how two teachers used the Better Math Teaching Network as a professional learning community to grow their teaching practice.

Case 3: Learners as Emergent Leaders

This is a case of how the network provided a space for three teachers experienced in student-centered mathematics instruction to continue to learn and improve their practice, while also informally serving as sources of expertise to other teachers in the network, and in so doing, taking on emerging leadership roles.

Chapter 1:

Case Studies of Teacher Participation



Case Study 1:

Collaboration and Spread in Rural Maine

The drive north into Maine is marked with noticeable shifts in the terrain. Since Maine still bans roadside billboards, acres of wilderness are the bulk of the vistas outside the car window. Once firmly in Maine, the landscape is peppered with small towns, beautiful lakes, and acres of woods. As we pulled into the dirt parking lot of the regional high school, we were enthusiastically welcomed into the school. We began our visit engaged in a long conversation with the school principal. She blocked out substantial time to meet with us—she was as eager to learn from us as we were from her. Her learner stance is representative of this school's culture, and the hunger for new ideas and opportunity is strong.

This school context is dramatically different from the urban and suburban schools that house other BMTN network teachers. While urban schools are often what come to mind when one thinks of poverty, the poverty observed here in rural Maine is different. Students travel long distances to get to school, and the winter is long. The local economy is not highly dependent upon academic attainment. In a world where few graduates leave the area for other opportunities, and many parents cannot find work, the value of education—and the place of math learning—is a hard sell.

Although the internet has made sharing ideas and resources easier over time, the principal points out their need to connect face to face with cutting-edge programs and organizations in order to continue to learn the best ways to teach children. Because the school is isolated geographically from these resources, the school embraces projects like the BMTN. In this case, it has been easy for the principal to support her teachers' involvement in the project since she respects the work of the Nellie Mae Education Foundation and knows that AIR brings important research knowledge and expertise.

In her words,

> *I think it's really important to have our staff connect with groups that are really forward thinking or looking at, how can we continue to get better? We want to benefit from the research that people are doing that sometimes we are not physically around in rural Maine; we have the internet, but I think sometimes the proximity of not being around major "think tanks" or having a university or college at your doorstep is isolating.*

She also spoke about her hesitation with some opportunities from outside groups, saying,

> *There are a lot of people coming at you to sell you a product they're claiming is just the magic wand you need. Because there's such a glut, I find it challenging in my role to sift through to find out what and/or who's the real deal and who isn't.*

But she sensed a difference in the Better Math Teaching Network:

> *When I hear things that talk about teachers collaborating, examining teacher practice, and names of reputable kind of sources… that right there is confidence.*

The focus of the network also resonated for the principal, as it fit with her vision for change in the math department:

> *I think with math in particular, some of the feedback that I have consistently given to our math teachers is, 'How do we move from the teacher at the board scripting the question and student at the desk practicing the question? How do we bring this to life a little more?'*

Additionally, the distinct population and challenges of rural living add nuance to the complicated job of educating high school students. The principal described her town and students:

> *We are in the, I would say, mid-60 percent [free and reduced lunch]. We have some schools in our district close to 90 percent. There are eight small rural towns that make up this school district. The local economy is made up of mostly family-owned businesses and farms, with few to no large employers. People in the small towns have a lot of pride in their community and our school. Many families have been here for generations and a lot of our students want to stay here; in fact, some of our students have never left even their own town.*

She explained how that context changed the nature of the school-student relationship.

> *There are not a lot of service providers in the immediate area, particularly counselors and others on the mental health front, so it often comes under the school umbrella. Some of the towns have rec centers; but their programming is more focused on younger students, and staff volunteers, so they're not open daily. There's not a teen center or a Y or anything in the area that high school–aged students can access regularly. So the students like being [at school] because some can live quite a ways from anybody else. It might be a mile or more.*
>
> *I think there's an honesty to our students that I think is pretty awesome. I love them, I think they're awesome, good people and that's why I try to motivate staff to continue to improve because the best thing that we can do for our students if we really care about them is give*

them a great education. We need to be supportive of them, but we can't enable them, either. And that can be a tough line. It can be a very tough line.

Despite the isolation and poverty, the principal does not use these realities as excuses for low student performance.

I think, at times, in the past, as a school we have used excuses for low performances like low socioeconomics or different sending schools. [Before I became principal] we sort of hid behind that to justify low outcomes, particularly on standardized tests for our students. I have a sports background; I'm a little bit competitive. I'm passionate about the students that we have here, and I just thought that is not acceptable. I believe our students have the capacity to do well and perform at a high level, all students. But I'm not naïve to the fact that we have a percentage of students that face a lot of challenges. I think that's where people can get lost in the balance of supporting students versus challenging them. I didn't want us to lower the bar because challenges get in the way. The challenges do not mean students do not have the capacity to do well. I think about what we can control as educators and try to keep the focus there.

"I didn't want us to lower the bar because challenges get in the way. The challenges do not mean students do not have the capacity to do well."

The school is a safe place for her students; she expects all of them to show up every day (despite some hour-long commutes), and she expects all of them to learn and graduate.

This school houses two network teachers: Ellen and Julie. Ellen is a veteran teacher. Despite her 21 years in teaching, she continues to explore possible areas of improvement with her teammate (and more novice teacher) Julie. Both teachers log work hours long beyond the school day, and they are very connected to their students. Ellen and Julie strive to find ways to open their students to a world of broader opportunity. As Ellen shared:

To them, [being a high school math teacher] is as top as it comes. They just don't know that there's so much more out there. They really don't. Most of our kids stay right in this area, and here they will be with their children.

Ellen and Julie believe math is a path to more, and that learning math can help them grow beyond their current possibilities. Ellen continued:

Sometimes I'll say, 'Well, some of you need to grow up to be smarter [in] math [than I am] because how are we going to grow if you guys all stay knowing less than what I know? That's not going to work as a society. Some of you have to go do bigger and better things.'

The Power of the Partnership

Both Julie and Ellen reported high levels of support from their school leaders and in the school culture. The school has an open-door policy, which allows anyone to (respectfully) walk into a classroom and observe. Ellen began to change her teaching before she joined the BMTN, in large part because of the school's open-door policy. She shared how she would go into other classrooms of different subjects and notice that the students were engaged:

I thought wow, some of those other subjects are having conversation, and kids are getting into it. I thought, we don't do that. I thought well, it's because I teach math. Finally, I'm like, but I want that.

So, [the math department] really tried to start doing something more engaging. They just... they were bored. They were bored, and we weren't getting results. If they were bored and they were doing super on the SATs, I might have left it like that forever because it was working. But if I'm not getting the results that I need, and they're not interested, how long are you going keep that pattern going? That doesn't make any sense.

Julie was also in a place in her professional practice where she was ready to do things differently:

I had been moving in that [student-centered] direction, but it wasn't until my third year of teaching that I was like, 'I really need to be doing something more with my math practices,' and I think that's what's moving me forward. I was getting there and then that was the same time the Better Math Teaching Network was taking applications, and I was like, 'I think this is where I need to be going.'

Despite her many years of teaching, Ellen independently continued to seek out ways to improve her own practice and continued to learn and grow. Julie was a novice teacher with a strong desire to learn. Like Ellen, she worked until late into the night at home; even in her down time she was thinking about math.

It came to me the other night, I was sitting watching television and they said something about division and I was like, 'No, that's not right,' what they were saying. But then it led me to think more deeply about divisibility, more specifically the question, Are a third of all numbers divisible by three? How would my students think about this question?

Once part of BMTN, she read much of the documentation other network teachers share on Google Drive (the network's space for sharing resources) and talked out ideas and problems with Ellen regularly. As they both made sense of their challenges, and strove to improve their practice, the common work that they explored deepened their own individual growth and served as a mechanism for broader spread.

Their partnership was strong and began prior to their participation in the BMTN. They both taught the same courses: Algebra I and II. Their classrooms were across the hall from one another. This proximity allowed them to pop in and out of each other's classrooms throughout the day, eat lunch together, and often debrief the day once the students had gone home. Julie reflected:

Sometimes I can be teaching here and my kids might be independently working and I might hear Ellen across the hallway doing something really cool and I step out and look over: 'What are they doing? This sounds really cool, really interesting.'

They covered each other's classes if needed, and constantly shared ideas and asked each other questions. Since they shared the same school context, what they attended to in terms of solving student problems was often similar. Ellen taught a higher ability level Algebra I class, so as they tested new ideas, they discussed variation created by their cohort differences. In some cases, Julie had to offer more scaffolding for her students.

When they ran into challenges with their work, they sought each other out:

> *Julie and I kept talking, 'Is that working for you?' I think it's been really helpful to have somebody in the same building doing the same work because if you have a couple in a row that don't work, you're thinking, 'Mine's broken. I didn't do this right.' But I think we had to train ourselves the same way we have to train the kids.*

Network structures, routines, and tools that support their collaboration

Although some of the energy and power of their collaboration and improvement efforts were certainly due to their own professional identities, personalities, and school leadership support, the Better Math Teaching Network offered multiple structures, routines, and tools that supported Julie and Ellen's collaboration.

Process maps

In the first network meeting of the year they learned about the process map, a tool used in improvement science to identify potential places in one's practice routine on which to focus improvement efforts. Ellen reflected on how this tool helped her develop her first change idea.

> *"We were talking about this and whoever was questioning me for my process said, 'Then what do you do with it?' I said, 'Then I move on with my next lesson.' I thought, huh. What do I do with it?"*

> *We were down there that week in July for the first [network meeting], and they said, 'We're going to do that flow chart, that process map of a routine that you have.' I said, 'Julie, I don't have any routines.' She said, 'Yes, you do.' I'm like, 'No, I just teach. I don't know.' I really just had this panic of, 'What is my routine?' I calmed down and I started thinking about it. I started thinking about teaching a lesson, go through the pattern that you see where maybe we work on a problem, or something.*
>
> *When I give the kids homework, it's usually more of just a skills-based thing, just that boring kind of stuff that I don't want to take up class time, but they still need to practice. … I give them what I call a learning check the next day. It's maybe two problems that look like their homework, just to give me a cue of are they doing it and where do we stand? We were talking about this and whoever was questioning me for my process said, 'Then what do you do with it?' I said, 'Then I move on with my next lesson.' I thought, huh. What do I do with it?*
>
> *That led to my first one [change idea]. As I grade them, I'm always noticing, there's always a common misconception or—take the problem I did today, not distributing that negative. Whatever it was, I would just blat out to them the next day, like that's going fix this for them. Really, you might as well save your breath! That's not very interesting. So, my first one was on justify and critique, where I gave them a problem that somebody else had done … and they learned to discuss math a little bit through that process, with what's wrong and why.*

They brought this tool back to their school and invited their literacy coach to help them with the process. Although she lacked math content knowledge, the coach knew classroom practice and

was able to ask good questions as they unpacked their classroom routines. As they worked through the process with each other and their coach, they identified areas in their practice where they could improve. Julie reflected:

> *When our literacy coach was working with me and Ellen on my process map, and we were at the end of my classroom routine, I stated that I didn't have great closure or wrap-up to the lesson. Class would end, and I might run out of time—they might quickly hand in homework or I might have a quick exit ticket. I had to look at that and think about: 'What can I do there?' That helped my closure get better. Going through that exercise really was a game changer*

PDSA cycles

The PDSA cycle is an important routine that frames the continuous improvement work of the network teachers. Teachers "plan" a small change in their classroom practice; they "do" the change, collecting data as they enact their change; they "study" the data to determine the success of their activity; and they "act" on what they have learned by adopting the change, adapting the change, or abandoning the change. Each PDSA cycle is tied to an element of deep engagement in algebra, as defined by the network: connect, solve, or justify. In their first cycle, Julie and Ellen focused on the justify DEA. As they tested different changes that gave their students more opportunities to justify, students became more comfortable talking when they critiqued the work of others and provided justification for their critique. This required the teachers to change their teaching (create a classroom routine in which students look at the work of others and share their thinking), but it also taught them to let go of their need to get through a set amount of material in a given day. In one of Ellen's lessons, we observed that every single group contributed an idea to the discussion, and they appeared to be completely comfortable sharing their ideas. Regardless of whether their strategy was successful, the students still wanted to share how they were thinking about it because it appeared that sharing was valued in this classroom. After the lesson, Ellen reflected:

> *We worked a lot on justify and critique. We worked on it in every aspect, not just those. When we were doing some board work, Julie and I both did the same PDSA, and we really worked on our questioning techniques to not lead them so much, so that they had more freedom to go in more different places. …they all shared out their different patterns. At the beginning of the year, they would not have done that. They would have gone, 'Uh shoot, I guess I was wrong,' and not shared. Now, because we've had so many conversations about how did you see it, and what were you thinking, and what could you have done, they're all thinking, 'Well, I guess mine's as good as anybody's.' Suddenly, everybody has something to say, which can be—it's a great thing and a hindrance.*
>
> *Sometimes I want to get more stuff done, but I've created this class where I want them to share, and now I have to give them the time to share. I feel math teachers in general have this thing where we have a mission and a plan, and we're so organized that sometimes I really want to stick with that. I've just come to learn to loosen up and just let some of that go. If I don't get to it, we'll get to it the next day because I think the benefit of having them all having some conversation here has just been so worth it. That was a lot of people owning their work and knowing that they're going to share something. Definitely worth it.*

An important component of improvement science is moving from the "study" phase into the "act" phase. Once a teacher tests out an idea and collects data, the data analysis and sensemaking is a critical—and often difficult—step for teachers. [See Improvement Science chapter, p. 52, for more

on this.] Julie and Ellen pushed themselves to use what they learned from the data they collected to enact their next step. Ellen explained how testing a change idea, learning from the data, and thinking about the network's resource for defining quality work allowed her to identify her next change idea.

> *This one started with just trying to hit all of those things that we talked about at the network meeting for quality. As I went through them, every problem gave me completely different data because I was using so many different types of problems. But the first thing that I really noticed was no matter what type of problem I had, the students' description of their strategy was never good. That's what made me tweak to coming up with, I really need to build out this strategy [with the students]. As a class, we spent a long time that day coming up with strategies and discussing them. That piece was actually data driven. The students didn't know what they were doing, and they just didn't know any strategies. They didn't know any names of strategies, and they didn't really know that they were strategies. Looking for a pattern to them was not math-y enough to be a strategy. I was like, okay. This is a place to start.*

The PDSA process helped them deepen their expectation for quality work and also gave them a new way to think about their teaching practice. Ellen explained:

> *I think when we started, we were so happy kids were writing, we gave them a lot of credit for things that really, they were just saying nothing. Now, we're more purposeful … this is where the network has come in handy. Before we read the criteria for quality that was given to us by the network, we think, 'What is a quality response to this going to look like?' We try to think that out ahead of time.*
>
> *I think that's where [PDSA cycles] been super helpful to me because now when I go to do something, I'm like, what do I need to give them ahead? What am I expecting them to do? I think they've just tweaked my thought process just enough that I get a better result out of it.*

"The PDSA process has helped them deepen their expectation for quality work and also given them a new way to think about their teaching practice."

BMTN student survey

Another network tool that guided their work is the student survey developed by AIR. Three times each year, all the network teachers gave their students a survey in which students reported their engagement in a variety of math practices—for example, "Do you solve math problems with multiple steps that take more than 20 minutes to solve?" These data help the network track progress toward their aim of increasing opportunities for students to engage deeply in algebra, and student data motivated Ellen and Julie to switch their focus from justify to solve.

> *Well, I think the biggest reason [we decided to switch to solve in December] is at the beginning of the year, [the Hub] gave us a survey. I looked through the questions and I read one, and I went oh, we're going to get a big goose egg on this one. There was a question that said, How often do you work on problems that take 20 to 30 minutes? I thought, only if they get stuck and sit there for 20 or 30 minutes. I wasn't giving them big problems that took them a long time to do.*

> *I think I didn't quite know how to get them to that point because our kids are not trained for that. They are behind the pack because they don't have some of those skills.* ***I think just having some structure here for—[the Hub] built out for us really, 'What does good problem-solving look like?' They gave us some things and I thought, well, I can handle that. I feel like they do for me what I do for my kids. They scaffolded for me what this needed to look like.*** *[Emphasis added.]*

Ellen gave her class the longer solve problems about once a week. "I don't have time for it every day, but I do feel that having enough time that is really super engaging with them carries through the rest of the classes."

Small-group coaching routine

The small-group coaching meetings were another routine that provided Ellen and Julie with support, learning, and an additional way to collaborate. For them, the small group was a way to continue to work together and get support from their Hub coach. Julie reflected,

> *We had a virtual meeting last week and I've been feeling kind of stuck …. The cycle before … we built out the problem-solving strategies, and in my next cycle [the Hub leader and coach] gave me the idea of 'How am I going to model for my students what it means to monitor their own progress? And maybe I need to do another anchor chart or poster,' because I'd been feeling frustrated like, 'I'm not getting at quality.'*
>
> *Julie: It's been slow but the Hub leader and coach gave me something to think about to move into [the next cycle]… She gave me an idea that I hadn't really thought about. I started the cycle with perseverance; maybe my next cycle I need to start with 'How do I monitor my solution? When I say, "I'm done," how do I know I've answered it right without [the teacher] needing to do it?' Because I can sit with a group and lead their thoughts, but that's teacher centered; we're working to get to student centered.*

School structures that support collaboration and spread within the school

The networked improvement community is a professional learning community in which people with different expertise and different roles come together to solve a common problem of practice. While individual learning is valued in a NIC, so too is learning generated to be spread beyond the individuals who participate in the NIC. This learning and spread is critical to the health of a NIC. This vision for broader learning drove Julie and Ellen. As Julie explained,

> *Kids always think that math is so prescribed and that it doesn't have any relevance to what they do when they leave my room, that they have to switch off their brain from everything else and be in math land. I don't want that. I want them to leave and be like, 'Okay, how am I going to approach this? And what's this pattern I see?' But they don't see that as math. They still see math as the nitty-gritty, writing equations and that stuff. I have to get them to think about the bigger picture and the math practices. And I think being organized, so how would we make this more successful for other NICs? Well, ideally I want this to go past what we're*

doing with the NIC. If I'm going to be committed to what we're doing here it's because I need this to play out in my own classroom, and I want to share with other teachers how successful this has been. I think that's why [I work so hard in the network]. And I need what you read and what you see I'm doing to be clear and organized.

Julie and Ellen received leadership support from their principal, which had an impact on their participation and the potential for their work to spread. The principal created a culture of learning and an environment where it is safe for her teachers to take risks, try new ideas, and share. Two structures that the principal used to build the support for Julie and Ellen's individual learning, and provide opportunities for spread of the learnings from the network beyond their own classroom practice were professional learning groups and a math team.

Professional learning groups

First, the entire faculty participated in monthly professional learning groups (PLGs). The principal designed these monthly meetings so teachers could meet by grade level, with meeting leadership provided by a teacher. The principal explained, "I've wanted the focus to be on topics that are in the locus of control of the teacher."

Ellen described how their BMTN continuous improvement work began to spread to other teachers in their school:

Julie and I were talking about this one day and all of a sudden, it's like quiet and everybody is listening. We're like, oh. Everybody was interested.

We took our justify and critique [PDSA cycle], but took the math out and ran through how we got to that point with our process maps. Some of them are starting to think about how they could use this idea of somebody's given an answer to this, what do you think about it? How could you build on it? What's good? What's bad?

I was like, this is not really a math thing. That part [of having the class critique an anonymous student's response] especially is not a math thing. We probably have seven or eight teachers who are supposed to try that in some manner in their class, and they're bringing it back to the next PLG. Apparently, Julie and I are going to facilitate the next couple of meetings. We are really excited that they wanted us to share our BMTN knowledge.

It is not only the change ideas that other teachers are trying, but also the structure of the improvement work:

We're actually going to have them do a process map next time because they're so intrigued. People are like, 'It's so different, and yet so simple. Whoever asked you to do a process map?' I said, 'I don't know what magical place it comes from, but when you're done, you just look at it and you're like oh, there's a hole there.'

I don't know, I think because [in doing the process maps,] you had to slow down and really think about: What is your day like? What are you doing with those things? I said, you just suddenly go oh. Maybe there's several; maybe you didn't pick the best one, but you picked a place to start. … That's easy. [We are] Definitely having an impact there with other departments.

Julie added that in that work, they also shared with their colleagues how they were trying to be more student centered. The facilitators of the PLGs told Ellen and Julie they had never had such positive feedback about a PLG meeting. Julie explained how the teachers were excited about the tool, and how it supported teacher learning rather than evaluation:

"You could just see people were like, 'Wow.' That process map, once you got it you were like, 'Wow, this seems really easy—I'm just going to detail what I'm doing."

You could just see people were like, 'Wow.' That process map, once you got it you were like, 'Wow, this seems really easy—I'm just going to detail what I'm doing.' And I'm really detailing what I do, what students do, where I make decisions, what happens after I make that decision and then go from there. No one's ever said, 'Maybe you should start there.' It's more about, what are you doing? What are you really doing? … And it's not meant to be an evaluative tool. It's more about, 'This is where I'm at and this is where I want to go.' That's all that tool really is… It's a learning tool.

They worked closely with one ELA colleague in the group who was interested in using the process map to improve her practice. Ellen described:

In the English world, they have so many opportunities for students to make choices that you could tell it was chaotic for the opposite reasons. There were so many decisions for students, they were like, no wonder they can't make a decision and move on. It was interesting how one thing could be used in multiple content areas and show completely different results. On ours we're like, 'Oh, the kids need to get more active,' and on theirs they're like, 'Yikes, we need to make some decisions here and move this thing along because now we know why this thing is taking six weeks and we wanted to do it in two.' The kids were just floundering. It was just really interesting.

I think Julie and I ran that for three weeks and it was probably the most interesting three weeks that we had out of that group because it gave us some focus and some purpose and—I don't know. It was just good stuff.

School math team

Second, the school's leadership supported math teachers' collaboration in a few ways. The math teachers had classrooms located in one wing of the school, and they had built-in times to collaborate with each other. They met frequently: department meetings, informal meetings after school, and extra meetings during the teacher discretion part of workshop days. Due to their proximity (they all shared a break room at lunch) as well as the built-in meeting times, they were a collegial group of teachers. As department chair, Ellen had the positional power to design ways to share the continuous improvement work with her colleagues beyond informal conversations. She tried small ways to share with her colleagues the changes she was making.

I'm hoping that people will try some more things. I did one video and I sent it around. If anyone wants to watch me teach—like you really want to do that! But some people do. I think that's one way that I'm trying to... my door's just open. If you want to come in, come in.

Julie and Ellen were able to successfully share one of the improvement science tools (the process maps) with their 11th/12th grade cross-content team since those tools and processes were content neutral. Their math team might be a space where they begin to share more change ideas that are math specific.

Spread beyond the school

Julie and Ellen were somewhat unusual in the network in that they began to spread their learning and ideas beyond their own classrooms in strategic ways. This was due in part to the strategic support of their principal, and in part to their confidence and capacity to take up the BMTN Hub's encouragement to share and spread.

Potential for district spread

The high school where Julie and Ellen taught was the only high school in the district. Three elementary schools, one preK-8 school, and two middle schools fed into their school. And these schools, in large part, had autonomous approaches to teaching mathematics. For this reason, their ninth graders entered high school with significant variability in mathematics experiences, skills, and knowledge. The principal explained,

> *We are getting students feeding into our high school from three different schools where they have had very different academic experiences, and it's not that one is necessarily better or worse but there are strengths and weaknesses that are coming from each school. But I think the biggest problem is that they are just so different. They are really different, and so we're having to invest time trying to build up common knowledge and skills for students. Again, this was an area that historically we may have let this be an excuse, a reason for our inability to move forward. We have to own what we do with those students from day one.*

The school district did not have a curriculum coordinator, but they offered stipend positions for a district-wide steering committee to work on developing curricular coherence within the district. Ellen served as the math teacher on this committee. In this role, she worked to coordinate K–12 math across all the district schools.

> *I think, if we could get [the curriculum] coordinated, [the students] would do better. Especially the elementary schools. Most of our elementary teachers are like other ones, where math was not their strength and they're fitting it in as best they can, but they don't really know the vision for where it's going, nor do they have time, when you teach every subject, to figure that out.*
>
> *As far as the K–12, I'm really working with them more on basic math … you should think about what you want for a result ahead of time. They didn't know we have math practices in math …. They're not ready for my PDSA cycle yet.*

Once that coherence is built, Ellen sees potential for spreading some of these ideas beyond her school. This suggests that there might be certain systemic conditions that need to be in place before introducing improvement science into the system.

State spread

While district conditions are not yet primed for spread, Ellen and Julie shared their work beyond the school to support the learning of other Maine teachers who were eager for intellectual stimulation and new learning. Though she was previously reluctant to present, Ellen's work in the BMTN gave her something unique to share and something she thought was worth sharing. She described this shift:

But now, I have something to share that other people are not going to tend to, so now I'm interested. I've never had something that I thought I did well enough that was different enough. I'm like oh, people should try this, and learn this. That's why we presented at the [Association of Teachers of Mathematics in Maine] conference.

The conference was in Northport, Maine, in the winter. The location and weather meant it would be a small audience, which helped give Ellen the courage to do it. She reflected,

Julie will just go talk to anybody; that's her kind of thing. I'm like all right, I have a partner that wants to do this. We'll go down there. I said, 'There won't be more than 10 people there; this'll be easy.'

At the conference they ran teachers through a math problem, modeled the process map and the PDSA cycle, and followed up with an explanation of how to engage students in justify and critique. One teacher who attended their presentation was a former colleague who subsequently applied to join—and was accepted into—the BMTN cohort for Year 2.

BMTN involvement accelerated their change in practice

Both Ellen and Julie described how, prior to their work in the network, they had been moving their practice toward more student-centered learning, which in part helped prime them to join the BMTN. As they reflected on their year, they noted things that had changed for them as a result of their involvement in the BMTN. Ellen described how she now plans differently for math class and how she presses her students.

When I was first starting out it was all about content. What was I going to show them? How did I want to hook it to something I was doing before or after? I was always pretty good about that. But I think what I'm trying to do now is try to figure out what are my kids going to be doing during this time? What are they going to be talking about? What are they going to be thinking about? And just trying to make the kids more of the focus.

I think our worry with students is we wanted to make sure they felt comfortable, and in the process of that they lost all opportunity to think on their own. So, it's kind of a delicate balance in between—because I don't want to leave them always on their own and feeling uncomfortable with math. It's just kind of a balance with your class to figure out who needs what and how much and that sort of thing.

Julie reflected on where she was four years ago, in the beginning of her teaching career, and where she is now.

I remember standing at my board 80 minutes and the only time I ever left was to go out and answer a question or to do proximity, like, 'You're misbehaving so I'm going to go stand closer to you.' That was 80 minutes. And now I think about everything I do where students are talking with each other or working with each other and it's our learning not their individual learning, and that's where I think I'm getting at the student centeredness: how am I increasing their learning as a whole—not as a whole person but our learning: What is their learning looking like? Not, what am I showing them on my whiteboard?

Conclusion

In their quiet and determined manner, Julie and Ellen embraced the possibilities of the network, from the tools of improvement science to the expertise and experimentation of their coaches and peers, in order to bring the rewards from this intellectually stimulating opportunity to their students, their school, and their rural community. Since they worked in an environment that is lean on this type of external opportunity and intellectual partnership, they grabbed onto all that the network could offer. Improvement science explores variation, and in this way the rural context of Ellen and Julie's work helps us better understand how this work gets taken up in different places that have different needs.

Through their enthusiastic participation in the network, they also deepened the network's learning. They tested new ideas, worked hard to document them so other teachers in the network could learn from their work, and shared their ideas broadly and openly. Within the network, their method of documentation became the model for how to document a PDSA cycle. They included their context, their steps, their tasks, their measures, and their student work. They explicitly identified what they learned from their testing and found ways to communicate their process through the write-up of each cycle. Both Ellen and Julie regularly put extra hours into the project, averaging between 60–75 minutes of work devoted to the network each week. Their willingness to share beyond the group at a conference inspired others to share more broadly as well; two other teachers will present at their local National Council of Teachers of Mathematics conferences. Their context is unique and the rural challenges are different from those faced by non-rural teachers in the network, but they were able to serve as a model for and inspiration to the network, their school, and beyond.

Case Study 2:

Network as a Critical Learning Support

Consider a teacher trying to use more student-centered instruction but lacking the local collaborators and resources to make those innovative shifts and work through inevitable challenges. This is a story that educators and reformers hear over and over, and while this story rings true for so many teachers, it describes a problem that continues to puzzle researchers and practitioners alike. Teaching is a complex practice, and teachers must continuously learn and be supported in that learning to
do it well. While educational leaders work hard to make schools and districts safe places for students to learn and teachers to teach, many do not have the resources to support all teachers in the specific ways that they might need at any given time. In the same way that students need differentiated support and scaffolding, so too do teachers.

While the two teachers in this case study worked in lively high schools with supportive leadership, innovative colleagues, and interested students, they each found themselves missing the critical support—at that moment in time—that would push their professional learning to the next level. They sought to become more student centered, to have models for what that looks like in an algebra classroom, and to have content-specific support from teachers who currently enact that practice or coaches with student-centered instruction expertise. The Better Math Teaching Network offered that critical support for Francis and Michelle, as it did for many other teachers in the network.

Francis was a fourth-year teacher and served as the only Algebra I teacher in his urban charter school. His school was focused on student-centered learning, he had a supportive principal, his colleagues

were innovative, and the school schedule included time for him to collaborate with his math colleagues. Yet, despite these supportive conditions, Francis had no one in his school to talk to about teaching algebra to ninth graders. A learner and deep thinker, Francis was hungry for content-based student-centered learning support and colleagues with whom he could dig into the "nitty-gritty" of improving math in his context.

Michelle was an eighth-year teacher in a suburban Vermont school. She had a supportive principal, a positive learning environment, and a large math team with whom she regularly collaborated. Over the years, she had two math colleagues with whom she worked quite closely; unfortunately, both left to go to other schools. She considered herself a fairly traditional teacher, but she sought to change this. A learner and collaborator, she actively looked for ways to move away from that traditional way of teaching math. She was eager to take risks, learn from others, and find new ways to deepen her access to new strategies, resources, and ideas.

How the network met teacher needs

Motivation to join

For both Francis and Michelle, the Better Math Teaching Network provided them an opportunity to join a community of like-minded practitioners who were working on similar challenges. While Francis had a math team with whom he collaborated, the network provided him an opportunity to collaborate with Algebra I teachers who shared his specific pedagogical content focus. This filled a critical need for him and was a large part of his motivation to join the network.

> *I feel isolated being in a small math department. As a department, I get to work with the Algebra II teacher, the Geometry teacher and the Pre-Cal teacher, but I'm the only one who teaches my content, so it's kind of hard to get advice or see how they teach a specific skill or concept in their class, to get feedback, or collaborate with other teachers. We do not co-teach nor can we co-plan. So I've been kind of doing that on my own for the prior two years before joining the network.*

Additionally, since Francis had a small math team at his school, he was motivated to join BMTN to broaden his professional network:

> *It seemed like a great opportunity to not only just collaborate with other Algebra I teachers and to see what they're doing, but to extend my professional network since I'm kind of plugged into a small network of other math teachers prior to being part of the Better Math Teaching Network.*

Finally, Francis was seeking coaching and instructional support that is specific to Algebra I concepts but only had access to coaching for general teaching practices.

> *The people who have given me coaching focus on protocols and routines around classroom management. I do think this is very helpful, that it's good to get that feedback because that's transferrable to many different contexts, especially in the communities I'm from and want to work with. But I haven't gotten that, 'Was the task engaging enough? What could have caused the disengagement?' I haven't gotten that [math] coaching and that's what I need*

and want. So I say that because being part of the network I got a chance to talk with other teachers and see what they do. I'm like a kid in a candy store! I can ask all these other math teachers who teach algebra, 'How do you support students with negatives? How do you introduce stuff with polynomials? That it's just numbers and letters—how do you apply it besides from a cheap word problem?'

Michelle embraced the collaborative nature of the network and the improvement science approach. The Better Math Teaching Network uses improvement science as a routine to support teachers' continuous improvement work. The improvement science methodology appealed to Michelle, as it reminded her of lesson study, a process of improvement work she did—with great impact—as part of her master's program.

Once I learned more about [BMTN], it really felt like it matched with what I wanted to do and what works with my favorite parts of my master's program. … I really, really enjoyed the lesson study process. The creating of these lessons together … I know that we're not necessarily following the exact lesson study protocol, but … thinking of math teaching as a science and trying to improve my skills in that. The few lesson studies that I was part of made such a huge impact in my teaching, and this sounded similar to that.

"Once I learned more about [BMTN], it really felt like it matched with what I wanted to do and what works with my favorite parts of my master's program."

In addition, Michelle was ready to become more student-centered in her practice, but she craved the structure and support to more deeply enact those changes.

I got to college and all my professors were like, 'You're too traditional. Stop doing that. This is bad.' I'm like, 'I don't know how to do it differently, and you're not really giving me concrete examples of what it means to do this differently, but you're telling me that my teaching is not good, and I don't know how to fix it.' But for me, when I started doing my master's work, it started to present me with some other ideas, but not necessarily the time to do the practice in my classroom. So [BMTN] is forcing me. I have to try these different things out with actual kids and see what happens and report on it and collect data. It's providing me with the opportunity and basically the job to make myself a better teacher, to force myself to try those new things, and to do something different than what I was doing before.

The network filled these multiple needs for Francis and Michelle. It provided formal and informal structures, routines, and tools to push their student-centered practice forward. And importantly, the network was content specific in all of its work.

Formal network structures supported their needs

Improvement science provides a routine for teachers' efforts to shift their practice

Throughout the school year, BMTN teachers engaged in their own improvement work by identifying a change they wanted to make to their practice and testing that change through a series of PDSA cycles.[4] In this way, PDSA cycles structured the flow of the teachers' work in the BMTN. For Michelle, this improvement science routine was a meaningful way to engage in continuous improvement.

> *We're creating lessons together. We're testing them out. We're collecting data and we're making a decision about whether that's a good thing to do or not and then no fault if it's bad. That's part of the research and you talk about why it didn't work and move on, but it also gives you knowledge about the students if one thing doesn't work or another and it's turned into me trying to be better at my job than I already am, but actually just getting the time [to do that].*

By engaging teachers in these improvement cycles, the network provided a structured process for teachers to try student-centered ideas. The PDSA routine created momentum for busy teachers, and it provided accountability to the improvement work, as the Hub leaders read and gave feedback on teachers' PDSA documentation. Finally, this routine provided important professional growth for both Michelle and Francis by allowing them to try something new in their classroom in a structured and supported routine.

Through her work in the network, Michelle was able to test a change idea from a former colleague that she had always wanted to try but had not yet incorporated into her practice: learning partners. At the beginning of a unit, Michelle had her students fill in a sign-up sheet in which they identified a unique classmate to be their learning partner for each of a variety of different topics. On the day that they worked on a specific topic, they would then have an automatic partner from their master sign-up sheet. This allowed them to work with a wide range of classmates while also giving them choice in their partners. She explained how she tested this idea in the first two cycles of her PDSA work:

> *My main focus on the first half—and almost both of my first PDSAs—had to do with the learning partners. The first one I did by myself [in the fall] was just getting used to using learning partners, establishing how are they going to choose learning partners, what kind of questions am I going to ask them in the learning partners.*

Two teachers in her school took up this change idea in their own classrooms after she tested it. In her second cycle, she focused on CRAVE, a model for supporting students' responses and justifications in math that some of the BMTN teachers used in the pilot year.

> *I actually switched over to a think, pair, pair model where they met with one learning partner and did the problem and then they met with another learning partner to review their work and see what they could do more to add to make it better—like a better CRAVE response; I*

[4] The PDSA cycle is an inquiry routine involving four steps: Plan-Do-Study-Act. The logic of the cycle is that teachers learn how to improve their practice by planning a specific change tied to a working theory of improvement, test the change, study evidence to assess whether the change constituted an improvement, and decide what action to take in light of what was learned. Identifying hypotheses, testing those hypotheses, and comparing results with one's predictions generates new details about how to improve practice. This rapid inquiry generates new learning and allows teachers the opportunity to examine variations in context that support or constrain their practice.

was more focused on that in the first semester because that had to do with what my [PDSA] project was.

Francis participated in the pilot year of the network and used the CRAVE model in his pilot year testing. Year 1 was his second year engaging in the improvement science work. He explained how he began his work in his second year:

In the [PDSA] cycles this year, I want to tighten the beginning and ending of my classes. I wanted do-nows [opening activities] to have purpose, to have engagement, to be student centered, and I wanted my closings to also be a little student centered but provide more opportunity for students to really think about the math they have accomplished or done in class and if they can make those extensions. So that's what my cycles were based around.

"The PDSA routine provided both Michelle and Francis the discipline, momentum, and accountability to carve out the time to try out new ideas and do deep, reflective work to improve their practice."

The PDSA routine provided both Michelle and Francis the discipline, momentum, and accountability to carve out the time to try new ideas and do deep, reflective work to improve their practice.

Small-group work a critical component of their learning and improvement

Another formal routine designed by the network Hub was the small-group coaching cycle. As teachers identified an area on which to focus their change (connect, justify, or solve), they organized into small groups. Each small group had a Hub leader who served as a coach. The small groups had time in face-to-face meetings to work together and would then meet virtually on a regular basis. Typically, the small groups met virtually once a month, but that varied for each group based on the flow of their work.

The small-group coaching cycle filled a variety of needs for Michelle and Francis. It gave them access to like-minded teachers solving a similar problem of practice; access to the expertise of the coach and each other; and a regular place to brainstorm ideas, test theories, dissect failures, get advice, and learn.

Francis's small group consisted of two teachers who also taught in urban schools. All three were teachers from the pilot project, so the previous year they had each worked in a small group that was focused on testing the same change idea. In December, they formed a group because they were all interested in improving their use of exit tickets in their classrooms. They all used the exit tickets for a different purpose, but they used a common rubric (designed by one group member) to measure the success of their tests.

Since they were geographically located near each other, from time to time they met in person.

When I met with [one member alone] we were working on our PDSA cycle together, but when we all met together it was mostly for a social thing, to just be able to hang out and spend time with each other.

In this group, Francis found teachers who were grappling with the same challenges he was, but who had different ideas and approaches. As one of his group members shared:

> *We would each try implementing our exit tickets twice a week for three weeks, and then we would talk about the data points that we collected which were all different, although we used the same rubric. Then talk about what were the successes and challenges, so I think it was a shared experience with a lot of variation. … For me, [it] helped me to think more deeply about that particular topic that I was trying to work on. … We were all doing the same instructional routine, but looking at it, I guess, from different perspectives.*

One of the teachers was a new teacher, like him, and the third member was more experienced. Their Hub leader used her urban school math coaching expertise to support their learning. In addition to the sounding board and math expertise he found in this small group, he also found new friends.

Michelle also built a deep relationship with her small-group partner. Michelle's fall small group had three other teachers new to improvement science. As they grappled with learning the new routines and tools of improvement science, they also sought clarity on how to find common work on which to focus. They had different ideas they wanted to try in their classrooms, and scheduling meetings and finding common work proved to be a challenge. In December that group split up, primarily to alleviate scheduling difficulties and allow them to more specifically focus their improvement work, and Michelle began to work closely with one colleague.

> *I feel like some of them were my ideas, but I was really interested in what she wanted to do as well. We tried to come up with a project that we both were excited about but that we thought would be an actual good project, that people would care about results. So I felt like the two of us together were a really productive team, and I enjoyed working with her.*

Michelle and her think partner met regularly, sometimes in the virtual setting with their Hub coach and sometimes in phone calls outside of those regularly scheduled meetings. This partnership proved to be fruitful for both participants, as well as the network's learning. At the end of the year, they collaborated on two change idea summaries (using formative assessment tickets and introducing new material with open-ended problems), sharing their learning broadly across the network.

Like Francis, Michelle also enjoyed access to the math expertise of the Hub leadership that the small-group virtual meetings provided.

> *I found the [virtual] meetings to be helpful as well. The Hub leader always had really good ideas about how we could make our project more streamlined and easier for us to tackle. And I felt that was helpful and kind of reined in our bigger ideas.*

Indeed, when she reflected on the people who most stimulated her learning in the first year, Michelle noted her small-group partner and the Hub leaders.

The small group filled a variety of needs for Francis and Michelle, including access to think partners and expertise, and it established regular ways to engage and hold them accountable to the improvement work. They built strong relationships with their think partners and tapped into the expertise of their coaches.

Informal Collaboration Provides Additional Learning Opportunities

In addition to the formally structured collaborative routines (the small-group coaching cycles and the face-to-face network meetings), there were many informal opportunities where network teachers could learn from each other. Both Michelle and Francis tapped into these opportunities and benefitted from them. This happened in a variety of ways, including connecting with teachers during meetings and utilizing other network resources.

Growing and learning by tapping into other network resources

There are a variety of ways that Michelle and Francis tapped into other network resources to grow their improvement work and their learning. They often utilized the available Hub expertise, leveraging the network's documentation system, making professional connections, and seeking resources from colleagues.

Utilizing Hub expertise

Francis and Michelle tapped into Hub leaders more than the average network teacher (as indicated by our social network analysis). Michelle told a story of when she sought out help from a Hub leader during a whole-group network meeting:

> *At one of those afternoon meetings, I sat with the Hub leader. I had some big ideas of what I wanted to do in terms of the type of questions I wanted [to use in my classroom]. … I wanted to try asking different types of questions to get my students motivated at the beginning of a unit, and I was kind of sick of me being the one that introduced the lessons. So she gave me some good ideas and different websites I could go to and find some problems.*
>
> *She kind of looked at the work that I was already doing in my classes and commented that she liked it and that it wasn't bad, but these were the kinds of things she suggested having before I got into those traditional notes and whatnot. That really helped me because then I started doing that throughout the entire year. I guess that was in the wintertime that we had had that meeting. From there I started adding those types of problems into my lessons for the whole rest of the year, and I felt like that was really productive. She helped shape the kinds of problems that I was working on.*

Leveraging the network documentation system to solve problems

Early in the year, Michelle was trying to make sense of the PDSA process and found Francis' documentation progress on Google Drive useful. While utilizing the network's sharing space, Michelle found a resource to support her through her moment of struggle, and in the process made a connection with Francis that they maintained throughout the year.

Making professional connections

In addition to sharing his work with the network, Francis shared some of his work more broadly. In the fall he participated in the Association of Teachers of Mathematics in New England conference by sharing his work with prospective members and attending multiple sessions. In addition, at Boston EdTalks in May of 2016, he presented through spoken word a powerful story about the importance of mentorship, how he sees himself in his students, and his work in BMTN. Sharing in these spaces broadened his professional network beyond the BMTN, especially now that he is part of the Teach Plus Policy Fellowship for the 2017–2018 school year.

Gathering resources from colleagues

By connecting with different teachers during breaks and in the small-group work times, Michelle and Francis both gathered ideas, strategies, and teaching resources. Francis shared:

> *I've also just gained other resources as well from just talking to other math teachers and the things that they use for other curriculum from Engaged New York to—I mean just so many other curricula that are out there that they use in their classroom and other resources that I could spend some time this summer and actually look over it, delve into some of it and say, 'Oh, maybe I'll use this. Maybe I'll use that,' because I'm coming from an experience where no curriculum was handed to me. The only thing that was handed to me was Common Core standards. … I can now spend more time under just the refining part for something that I may be given.*

What they learned

Francis and Michelle were relatively new to student-centered instruction, and they were both at a place where they were ready to deepen its enactment in their classrooms. As Michelle described,

> *I felt confident in the content, and I was ready to abandon some of my traditional styles and bring in some of these more student-centered [approaches] where the students are working together. I'm not just the one who's making all discoveries. I'm allowing them to talk to each other and learn from each other.*

When asked to reflect on what changed for them as a result of their involvement in the network, Francis shared:

> *Now I know more specifically how I want to grow. Going into the network I was just like, 'I'm on an island by myself, so I'll take anything and everything. Go ahead. I'll take that. I'll do that. Give me that book. I'll take that.' And I definitely did that. I have five books about math discussions and reflection and having students do things in the classroom …. I think now, by going through this process, I am trying to be more intentional about what it is that I need and trying to digest the small things one at a time. That way I can see, 'Okay, I'm learning from this, I'm reflecting on that. Can I try and implement that before I introduce something else?'*

So I think that's something that's a change for me because that was not me in my first two or three years of teaching. It took me a while to get to that point to really understand what it is that I'm really good at, what my growth areas are, and to plan every problem, activity, and response with clear intention.

… By thinking through the intention, just by the natural [rhythm] of the PDSA cycle and collecting the data, it slows me down to digest exactly what is going on and make changes that are influenced by my data and not just a kneejerk reaction.

"... By thinking through the intention, just by the natural [rhythm] of the PDSA cycle and collecting the data, it slows me down to digest exactly what is going on and make changes that are influenced by my data and not just a kneejerk reaction."

And Michelle reflected:

My confidence has changed. When I first started working in the network it was a little intimidating to feel like everything needed to change. That was definitely an overwhelming feeling in the beginning …. And I feel like now, I've definitely moved further along the spectrum in terms of providing material for my students, getting my students thinking, and getting them a little more centered in the classroom as opposed to me being the one who is providing all the learning—which doesn't make a lot of sense, I get that. I've always known that wasn't the right thing, but I didn't know how to make that switch.

She also described how she became more intentional in her teaching as a result of her PDSA cycles. By expecting her students to reflect on what they had learned at the end of class, she had to make sure that she was clear in her teaching.

When I was doing the formative assessment tickets I had to be very clear about my teaching. I can't expect them to get this big idea if I'm not even clear what the big idea is and if I'm not teaching them how to do that. Obviously, there's some balance between just directly giving them the answer and having them figure it out themselves.

And finally, Michelle reflected on the changes in her teaching practice.

But I do think that's kind of shifted in my teaching as well. I want to provide opportunities for them to think about those bigger ideas and to come up with them on their own instead of me either skipping over it or giving it to them.

Francis reflected on how he might marry his other interests with the improvement science process to affect his teaching practice.

I remember being in grad school and doing an independent study on video games and how to use them in the classroom. Not so much gamification, but looking at the video game design principles that make a game engaging and functional. I want to go back to that research and perhaps do PDSA cycles on ideas that implement video game design principles in my math classroom to foster student engagement.

What they shared

The work products and learning Francis and Michelle shared with the network sparked ideas for other teachers within the NIC. In Francis's case, the rubric that his group developed and the different purposes for exit tickets were ideas that sparked interest for other teachers in the network. Likewise, the array of resources and ideas Michelle and her think partner contributed in their change idea summaries became a resource for the network. In her last change idea, Michelle and her partner thought broadly, wanting to move the improvement beyond her own practice. She shared:

> *We didn't want to do a traditional exit ticket that, like, we felt was something that had to do more with the content of the day—'Can you show me that you can solve these types of problems that we've been working on all day?' We wanted something that was general. I was kind of sick of being stuck in my own little bubble and feeling like, okay, the work I'm doing is great and has really improved my teaching but is it going to improve anybody else's teaching? And so that's why we came up with the idea that we wanted to do something that was more general, more vague. That maybe anybody could just take and use in their classroom.*

Conclusion

The collaborative element of the network and the opportunities to learn from others with practical experience and content expertise were powerful draws for Francis and Michelle to join and engage in the network. They were newer to student-centered learning and looking for models and supports to help them shift their practice. The Hub leadership provided high-level, math-specific coaching, which both Francis and Michelle accessed regularly. The other network teachers provided them with ideas, resources, feedback, and social support.

Network routines and tools helped maintain momentum and encouraged them to take new risks in their teaching. In addition to the PDSA cycle that gave Francis and Michelle a structured routine for improvement, network routines added an accountability element; they had to prepare to meet with their small groups, complete PDSA documentation to submit to the Hub for feedback, and create presentations to share in whole-group meetings.

As a result of their involvement in the Better Math Teaching Network, Francis and Michelle were able to access the resources they needed to deepen their student-centered teaching practice. In doing so, their collaborative involvement and the work they produced strengthened the network. Both Francis and Michelle's powerful collaborations resulted in ideas and resources that were shared more broadly within the network.

Case Study 3: Learners as Emergent Leaders

The Better Math Teaching Network brings together a collection of like-minded high school math teachers from various towns, schools, and cultural contexts to solve a common problem of practice: many students who take Algebra I courses in 9th grade are not deeply engaged in learning the mathematics content. The teachers came with a wide range of high school math teaching experience: between 2 and 29 years. Certainly, one might assume that the new teachers had a lot to learn from other, more experienced teachers in the network, and that experienced but more traditional teachers who were grappling with how to shift their practice to more student-centered instruction could also learn from others.

But what about the experienced teachers in the network who were already student centered in their practice? Teachers who have already successfully enacted student-centered learning likely have a repertoire of instructional strategies for promoting students' deep engagement in mathematics in Algebra classes. Why might they take on the challenge of learning to use improvement science methods? What role might teachers with more expertise in student-centered learning play in the networked improvement community? In this case, we introduce three teachers who fit this description: Pam, Julie, and Tara. We explore how they enacted three primary roles in the Better Math Teaching Network: as learners, collaborators, and emerging leaders. Additionally, we explore their vision for what a networked community of high school math teachers can do to advance the field toward more universal student-centered instruction and deeper student engagement in high school mathematics classes.

Veterans enacting student-centered instruction: Pam, Julie and Tara

Pam is a veteran teacher, with 29 years of experience. She writes her own curriculum, builds rubrics based on the Common Core standards, has used proficiency-based grading for years, and is committed to student-centered teaching. She works in a STEM charter school, which is relatively new and has promoted a commitment to design thinking. Pam explained how they use design thinking to solve problems, "Whenever there's a problem that pops up, what's the problem? Let's really dig and find the problem and then let's use some design thinking, which encourages divergent thinking about solutions to the problem." This school context enables her to be highly creative and innovative in her teaching. Pam's instruction is decidedly student centered: she believes that the classroom is about the students in the room rather than covering a set curriculum. She designs tasks and activities with each individual class in mind, flexibly changing mid-lesson if the students' learning needs point her in a different direction. She gives the students problems or data sets to ponder that are interesting and meaningful, and that prompt the students to think. She engages the students in lots of discussion, allowing long periods of wait time which give students time to think while also setting the expectation that they will contribute something, even if it is just the beginning of an idea. In addition to teaching, she runs professional development sessions at math conferences, blogs regularly, and thinks deeply about her practice.

Julie has been teaching high school mathematics for 19 years, including 4 at her current school. Julie described how the professional development she received at her current school transformed her teaching: "Now I came to this new school which has much better resources … and experienced the most incredible professional development that has totally changed how I teach. It's much more student-centric based. We had intensive, three-year professional development with studios." Sharing an illustration of this shift in her practice, Julie said, "We had just developed a generalization. A student said, 'Should we have this memorized for the next assessment?' This kid in the front row turns around and goes, 'Why would you need to memorize it? You just figured it out.' I was like, yes!"

We observed Julie facilitating learning and encouraging students to engage in mathematical thinking in a variety of ways. In large group discussion, she prompted students to build upon what she heard in their small-group discussions. She created opportunities for students to discuss converging problem-solving approaches. She prompted students to make their claims explicit and drew in other students to summarize what they heard. Students analyzed student misconceptions, as Julie asked them, "Why do you think they made this mistake?" Students in her classroom engaged deeply in mathematics and discourse about mathematical thinking.

"A student said, 'Should we have this memorized for the next assessment?' This kid in the front row turns around and goes, 'Why would you need to memorize it? You just figured it out.' I was like, yes!"

A teacher with 13 years of experience, Tara was the team leader for the math department at her Vermont high school and has contributed to the development of her school's Common Core–aligned curriculum. She had a strong collaborative team in her school and benefitted from an innovative district context. She explained, "I would say that this high school definitely supports risk-taking, trying new things, encourages it …. I'd say that as a teacher I am pushed by our school level administration through what happens in professional development …. I'm in an environment where that's allowed and encouraged, and enjoyed, and people are psyched that I'm doing this work." Tara's classroom exemplified many markers of a student-centered mathematics classroom. We observed

her providing opportunities for students to make their solutions to open-ended problems public and explain their mathematical thinking. She encouraged students to analyze these solution strategies, sometimes revealing misconceptions in the presenter's approach. Students helped each other move to accurate solutions, and students seemed comfortable getting this support from their peers. Additionally, she utilized innovative activities to promote deep engagement with algebra content such as a problem-solving scavenger hunt and the use of an app called SeeSaw that enabled students to take a picture of their work and record an audio clip of their explanation.

In sum, Pam, Julie and Tara are three experienced teachers who have embraced student-centered instruction. They work in supportive contexts and have generally had rich opportunities for professional development. In the remainder of this case we illustrate how these accomplished veterans engaged in the network and the benefits they perceived of network participation.

Embracing the network's press for and structured approach to continuous practice improvement

Opportunities to learn using the improvement science approach

All three teachers positioned themselves as learners, despite their accomplished practice. For example, Julie noted that her priority was to spread student-centered learning ideas, but acknowledged, "At the same time, it's good for my practice as well …. I have lots of growing left to do."

Pam was motivated to join the network largely because of the continuous improvement aspect of the work, specifically the improvement science methodology. She explained:

> *I've always been on a search for improvement, just always doing things better, because I know that I can always do things better. But then the other piece of it that was intriguing to me was the improvement science—building from industrial quality control in ways that were different, because I knew a little bit about that. After a whole year of being part of that pilot group, it occurred to me, wait, my brother has been doing this for 35 years! He knows something about that. But in the industry, in the business world, not in education. So, I had a conversation with him, and he helped me to understand things too, on a deeper level. It brings together different parts of my brain to help me be a better teacher.*

She reported that the improvement science aspects of the network were her biggest opportunity for learning:

> *As far as learning this year—well, I guess with both years, the learning curve, the steep learning curve was about how do you write a PDSA, how do you learn from these cycles, and that's a pretty steep learning curve.*

Pam valued the feedback and reflection the process afforded her:

The thing that I really appreciate the most is the feedback that we get, the feedback that we get from Hub leaders on our plans pushing to be more specific or pushing for, 'How are you going to define this?' … things like that. And also, the feedback that we get from our colleagues when we talk about how things are going and what we're doing. Whether it's through a virtual meeting or the face-to-face meetings, just having that time to sit and process the results of what's going on, and how people ask questions and listen to the successes that they've had. All of those things push me to think about my practice and improve it. That's the really valuable part. It's a type of professional development that I've never had, and this is my 29th year of teaching.

Social pressure within the network culture to continue to improve practice

All three teachers appreciated the "push" or "press" the network placed on them to further refine their student-centered instruction.

It's really pushed me to think hard. It's pushed me harder than anything else has pushed me to think about my practice …. It makes me think really hard about the flow of a class or the flow of a lesson, when I'm thinking about what works, what I think is working and what isn't working. It makes me, it forces me to confront the reality [laughs]. This piece of what I do can use some improvement. And then it forces me to think about how the heck am I going to do that, and come up with a plan. [Pam]

I think that even when you start to dabble with some student-centered approaches and you're trying to put students more in charge, you think you're doing things that are student centered. And you are, but I think that the Network has pushed me to take bigger leaps. [Tara]

"It's really pushed me to think hard. It's pushed me harder than anything else has pushed me to think about my practice...It makes me think really hard about the flow of a class or the flow of a lesson, when I'm thinking about what works, what I think is working and what isn't working."

Their accounts suggest that the network was providing structure, methods, and accountability for engaging in inquiry-driven practice improvement. Julie explained:

I've always been a teacher who tries new things out and amended and made changes and adapted. I've done that without the structure [of the PDSA cycles]. The one thing I would say about the structure is that it creates accountability to make that change or test that change now. So, it does provide, for me, almost a motivational immediacy to try it now rather than later. So that's what I'm finding to be the most useful piece of the PDSA so far.

She appreciated the structure that the PDSA cycles offered, though she was still struggling with the data aspects of the PDSA cycles. She explained: "Getting that self-discipline and structure from the PDSA cycle is useful. But I don't necessarily know that the data I'm getting from the PDSA cycles is moving my teaching forward more than it would without it. But it's definitely pushing me to go ahead and try those change ideas in a structured way."

Like Julie, Tara valued the structure and accountability of the PDSA cycles. She shared,

> *I often try new things in my practice, but having the accountability of having a PDSA form to fill out and a group to report back to and a timeline to follow and surveys and data to collect hold me accountable to do some of those instructional changes that I might want to do on my own anyway, but [it's hard to put time] aside because life is busy and teaching is busy and the day to day that we do with students takes up a lot of time and energy.*
>
> *Working some of those things in you have to be really deliberate about and so [BMTN work] just kind of carves out that time and forces me to be good about those things. Even if I wanted to do them otherwise, being part of this group would hold me more accountable to following through with them.*

Pam, Julie and Tara all identified improvements in their practice that they attributed to the network. While not specific to an algebra class, Pam worked on how to make her statistics course more student centered and came up with an entirely new way to structure the course. Julie said, "I definitely had multiple new strategies that I implemented as a result of this work this year." Tara used the PDSA cycles to focus on new ways to get her students engaged in discussions about mathematics. Using a strategy that some BMTN teachers tested in the pilot year, Tara engaged in improvement cycles to build students' justification skills.

Collaborating with a range of network colleagues

Related to the learning opportunities and press to improve practice these teachers experienced, Pam, Julie, and Tara all reported appreciating the various opportunities to collaborate with teaching colleagues and network leaders through participation in the network. Tara pointed to opportunities for collaboration as her prime motivation for joining the network.

> *By having this broader network, I think we're very powerful. I work really closely with my colleagues at school. We really have a lot of autonomy in what we do, and we are highly collaborative. So I just know that any time I can collaborate with a team, it just makes my work that much better. Being able to join that collaboration is a really large motivator for joining the network.*

Julie also found the collaborative aspect of the network valuable. She shared, "I love the colleagueship. I've definitely made contact with other people I feel I can rely on or contact for resources or ideas." She worked closely with Tara, who was her small-group think partner, throughout late winter and into the spring.

Like Tara and Julie, Pam valued the collaborative structures the network provided:

> *I think we've had some really good conversations within, when we've had group discussions, when we've had the small virtual meetings. I think that we've developed, or at least I have, I mean, I can't speak for everybody in the network. But I've had some really good teams that I've worked with. And my little group, my little PDSA group, I really like a lot. Like I said, they sort of push and ask questions and probe and things like that. So that's helpful.*

Pam also utilized the Hub leaders' expertise frequently, connecting with all three Hub leaders outside of formal network meetings.

Related to the prior section, Tara found her press for practice improvement in her deep collaboration with Julie, facilitated by the small-group coaching meetings. Tara said:

> *In a similar way this whole network, [Julie and I are] pushing each other to try those new things. … I think having those connections with other people who are like-minded, who are doing that pushing part, which, I don't know that you're ever going to find a whole math department in any one school where everyone's like that.*

Julie expressed a similar sentiment:

> *Tara and I have been working on some similar things. What's really cool is she started to become very interested in this idea of using tasks and student ideas to introduce concepts. She has not had this training at all, but she was very interested in how I got students to think about solving systems. In Algebra II, some of my students recalled how to solve systems. From them, we got how to solve systems. But in Algebra I, none of the students knew how to solve systems. They figured it out by working together; they made sense of it. … Tara was very interested: 'How did you take this group of really struggling students and get them to make sense of how to solve simultaneous equations?' She listened to their process, and we talked about it.*

> *She was about to start a unit on solving systems, and she came and met with me during exam week. We both had a little time, and we looked at the sequence of tasks I used. She adapted and tried some of them.*

"Since they had experience implementing student-centered learning and worked in schools that supported this innovative work, Pam, Julie, and Tara were positioned to help other teachers in the network."

In general, these experienced teachers appreciated the opportunity to exchange ideas and commit to continuous practice improvement through ongoing substantive interaction with teaching colleagues who shared a commitment to student-centered mathematics learning.

Emerging leadership role in the network

Since they had experience implementing student-centered learning and worked in schools that supported this innovative work, Pam, Julie, and Tara were positioned to help other teachers in the network. Julie shared one perspective on this role,

> *I think just because of what I've gotten from my school I'm not really in it to change my practice so much as to help other people [change] their practices, to share what I've been really lucky to get through my current district. So it's not that I am an awesome teacher who came up with the way to teach this way, but I'm lucky enough to have been given this opportunity and support and to see how drastically different and better things can be.*

In network face-to-face meetings, all three teachers shared wisdom, examples, trials and errors, and resources. Analysis of the whole-group discussions during meetings shows their contributions tended to be frequent and meaningful. They tended to contribute by offering advice, sharing their own practice, pushing the group's thinking or actions forward, shifting the group's thinking about the nature of a problem or its solution, and/or adding nuance that deepened the conversations.

They gave advice from the pilot year:

> *The PDSA purpose is to move your teaching toward more meaningful math. When you read a book, you have the intention to change. But there is something about writing it down, and I'm accountable to myself and others. Making yourself do it is sometimes the hard part, so there's a lot to putting it to paper.* [Julie]

They shared what they do:

> *I told my [students] what I am doing, and that motivates them. I said to them, 'Can you imagine that in the course of my day some students sit back and let others do the talking/work?' Yes, they can imagine that. So I tell them, 'I want everyone to engage.' … I told them: 'I want you to have these conversations without me as a mediator. What I want you to do, before we discuss this problem, is have a question for your classmates. I was writing down strategies I saw you doing. I want you to share the strategies.' I was trying to get them to have an interesting and quality discussion. Were they sharing a strategy? Were they asking a question? Clarifying or probing? Their questions were more probing when I stepped back.* [Pam]

> *I asked my students: 'Can we see your thinking? Can we read about it? Can we see math evidence (visual, numeric, …)? Can you convince us the pathway leads to a logical solution?'* [Tara]

They pushed the group's thinking forward and moved the group along:

> *What would we want to see from a student? What evidence would we want to collect?* [Tara]

> *We are hung up on this problem. You can start with something more procedural ….* [Tara]

> *Let's talk about that at the next meeting once we have tried more cycles.* [Julie]

They pushed their colleagues to think differently about how they assessed the usefulness of problems and/or how they then implemented the problems in the classroom. In one meeting Pam shared an observation: "There is all kinds of potential [for how to use this task] … but the task itself is not asking anything other than procedural." At which point Tara built on: "It's what we do with this."

They brought nuance to the conversation:

> *The reasoning is correct, not that the answer is correct.* [Tara]

While Tara and Julie were each other's small group, Pam engaged with a small group of teachers who were new to the network. In these interactions, she shared her deep knowledge of improvement

science, things that she had tried in her classroom practice, frank stories of attempts and mistakes, and an openness to learn and grow.

These three teachers also influenced other teachers in the network in more informal ways. They modeled taking risks and failure, and they offered resources and advice in side bar conversations. Other teachers in the network recognized their expertise. In the spring administration of our network survey, we asked teachers to identify which teachers in the network they most respected regarding opinions on teaching and learning, and Julie, Pam and Tara were identified as the top three teachers for this area.

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Vision for the Better Math Teaching Network

Pam, Julie, and Tara all expressed passion and commitment to the BMTN's network aim. Tara described how the network's vision resonated with her interests:

> *It's definitely a cohort that I'm passionate about [9th-grade Algebra students] and I want to see improvement with. It's also a group of students I find when they enter in 9th grade that don't always see themselves as math people. I really believe any student can learn math regardless of where they're coming from and what ability they have. I work really hard to try to get students to see themselves more as math people.*
>
> *Algebra I, I think, is really a great gateway into that. It allows me to be the first experience students have in high school math. And so having a way to work with other teachers throughout New England who are kind of working on the same goal was really a big motivator for me. I also think, as a high school math teacher, we're always fighting an uphill battle against a society that doesn't always see math as something that's as important as maybe some other disciplines, and [that] thinks it's okay to not be a math person.*
>
> *Which is another thing that I'm really passionate about. And again, I think being a high school math teacher, particularly with the algebra cohort, it really gives me an opportunity to have a positive influence on students and to really break that negative connotation about it by having other ways to figure out new ways to get students to learn math, new ways to engage students, new ways to approach material.*

When asked about her vision for what this network could accomplish, Tara said, "I want it to change math education in the United States."

Similarly, Julie talked about spreading what the network is learning with the field: "In the network and/or in Vermont and/or with my student teachers. So no, it's definitely beyond this district that I'm [thinking] …. To me, it's a math-teaching movement spread that I would love to help with." It is interesting that both teachers framed the shift to student-centered learning in language consistent with mounting a social movement.

Pam also saw the potential of what is learned within the network to spread beyond the BMTN teachers:

> *The people in this network are changing the way they teach. But then, how do we expand that? How do we get to the people who aren't in the network, to say, "Look, if you want to engage kids with algebra, you have to do things differently"?*

While embracing this notion of a movement in the mathematics field, Julie reflected on the role that BMTN is positioned to play in this charge, noting her concern that broadly spreading student-centered learning practices in education will require changing systems, not just individual teachers' practice.

> *I think this network, as far as it is motivating the individuals involved to really try to change or to open up their practice, is a really good thing. But I'm not sure how much people can change without the schools they're in changing, without their supervisors being brought in on the process. If there isn't a fundamental belief in what we're doing in their departments and their schools, I'm afraid it'll just peter out like a cool experiment. Maybe they'll have a few small student-centered tricks up their sleeve that they could pull out here and there, but that isn't going to fundamentally change what they do. I feel like for really fundamental change, the [professional development] needs to be more intense and more inclusive of their system.*

In general, Pam, Julie, and Tara were thinking broadly about the work of BMTN as a networked improvement community and how it can be structured for maximum impact. In interviews and conversations, they wondered about the best way to get teachers in the network to develop a vision for student-centered practice, how to ensure teachers have access to expertise, and how the network should approach scaling its impact.

> *I think I mentioned to the Hub leaders that it would be really good for us to do math together. I think that one of the challenges, as I listen to others talk about their classes and the work that they're asking students to do, and the conversation that we had a couple weeks ago, about quality and tasks and all of that, I'm not sure that everybody is on the same page about not just quality of learning, but quality of opportunity. Like, what makes a quality task? And so, if we were to do more of that when we get together … let's get some quality tasks in there so the people understand that it's not just about what the exercises in the textbook are or what Kahn Academy is telling you or that kind of practice. But there are other ways that you can get deep and rich problem-solving and learning happening without practicing procedure after procedure after procedure.* [Pam]

> *This step to scale—is writing up a change idea and passing it on really enough? I guess the acceptability of let's package some ideas and get people started, but I feel like the change is so fundamental that small things may end up just being surface …. I'm not sure people really get the fundamental vision of what is different in the classroom compared to the way we currently teach.* [Julie]

We think their capacity to ask these broader questions may relate to their experience with student-centered instruction. For most teachers, the BMTN work has two layers of challenge: learning to implement improvement science and learning to be student centered in one's teaching practice. Since the work did not put significant demands on Pam, Julie, and Tara's pedagogy, they had more cognitive bandwidth to learn improvement science and think broadly about how improvement science can be utilized to drive ambitious instructional reform. In addition, given their interest and capacity for asking these broader questions and thinking systemically, these teachers are positioned to take on emerging leadership roles in the network.

Conclusion

Overall, the network's focus and structure motivated the engagement of these experienced, student-centered teachers as both learners and emergent leaders. The network provided avenues for these teachers to both share their expertise and grow their own practice. These particular teachers are poised to take an expanded role in the leading the network's work to ensure that more 9th-grade Algebra I students in New England—and beyond—are deeply engaged in mathematics.

Chapter 2:

Teacher Participation in The Better Math Teaching Network

A networked improvement community must develop structures and activities that provide opportunities for members to productively engage in collaborative improvement work. Additionally, it is optimal that these designed participation structures enable a range of types of participation in order to engender the commitment of professionals with diverse interests and capacity for engagement. These are voluntary organizations that require working professionals to find the time in their busy schedules to do work that is often seen as an add-on to their existing commitments. Consequently, network leaders must be strategic in the way they create and market opportunities for participation. In this chapter, we report our findings about participation in the first full year of the network's development.

The design of the network fostered a community of like-minded and passionate teachers

When initially forming the network, Hub leaders made strategic decisions about the composition of the network that likely contributed to robust participation and engagement. First, the selection of a focus on student-centered learning in mathematics attracted a set of teachers who are passionate about engaging more students in algebra. Over half of the BMTN teachers identified this mission as a motivation for joining the network.

> *Student-centered learning is a huge goal of mine, and just the idea of being able to talk with other teachers and network, and expand my base of other professionals that are doing the same work that I am—to collaborate with them and get new ideas with a focus to be able to bring that back to my students.*

> *It really caught my eye because it gives me an opportunity to collaborate with people who are interested in the same stuff as I am, student-centered learning.*

> *I was really interested in the mission statement they had online and their key points about engaging more students in algebra.*

Through a competitive selection process, network leaders identified a diverse set of teachers—ranging in teaching experience, geography, and student demographics served—who are committed to providing their students with opportunities to deeply engage in Algebra I courses. In whole- and small-group meetings, teachers eagerly and passionately talked about mathematics content, teaching, and learning.

> *When you're in a room with 25 other people who are just as interested in helping these ninth graders learn algebra, in new ways, I think that's really helpful.*

> *We're all professionals. We're all working toward the same goal of helping our students understand math in a better way and how we can support each other.*

> *I mean, the opportunity to work with math teachers who are from New England. The first four days we did nothing but talk about math. Even when we weren't being told to discuss something, we were talking to somebody about, 'What do you do at your school? How do you teach this? What's your pacing for this? Do you think we should teach this before this?'*

It was just incredible. So much talking about math—which, unless you're a math teacher, you don't really get why teachers want to talk about it that much because we don't have that many people who want to have these conversations with us.

And the network fills a void for many teachers who lack robust opportunities for collaboration and interaction with other mathematics teachers in their local communities of practice (see chart essay on school context, for more details).

The network created a range of participation structures to promote teacher engagement

The Better Math Teaching Network designed a set of participation structures that are promoting high levels of teacher engagement. These participation structures include:

- whole-group face-to-face meetings,
- smaller working group virtual meetings, and
- opportunities for informal interaction (both inside and outside of meetings).

Whole-network face-to-face meetings

The network supports teachers' travel to Boston for quarterly face-to-face network meetings where teachers have opportunities to learn improvement science methods, discuss the integration of this approach into their math practice, and share what they are doing and learning. Teachers noted that the network meetings were great opportunities for learning.

Whenever I come back from the network days, I feel really excited about teaching math and energized. So I really enjoyed that aspect of it.

At our whole-group meetings, when people would share out their different ideas and you could hear how the whole thing went—that part was my biggest takeaway …. I like the fact that we got to hear something from everybody.

I got the most out of those [face-to-face meetings], actually sitting next to the teachers that we were all working with. I'd say the most influential thing for me was really actually getting to sit down with everyone and relate to our material in that way.

Additionally, face-to-face meetings serve to build community and generate social connections that allow for informal interactions during formal meetings and can spark informal interactions outside of formal meetings.

I listened during the whole-group meetings, and then if I had any particular questions about what one person said I would go over and talk to them afterwards.

For one rural teacher, the whole-group meetings served as a way for her to learn what other teachers were working on and make connections with new teachers. She explained the value of the meetings for her,

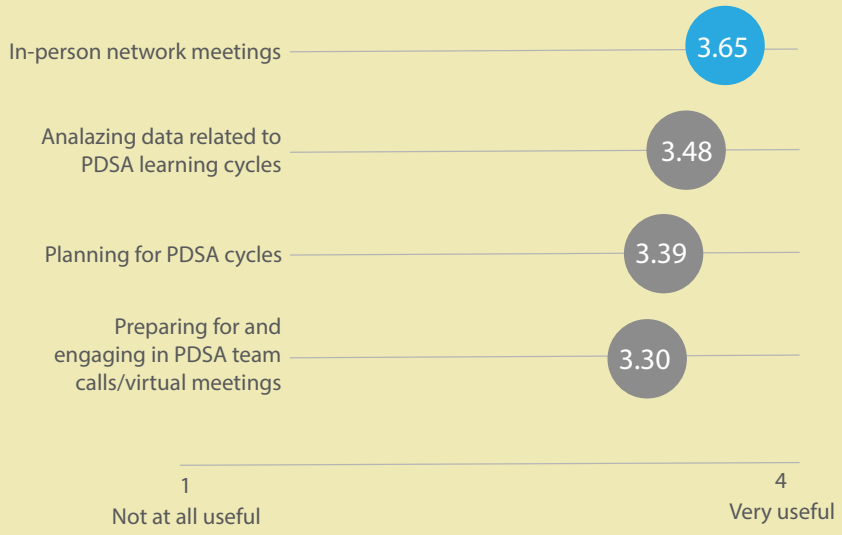
To be able to talk to people from different districts whose departments are in different places, and who think about content a little bit differently, to be able to pick their brains about the way that they present material is really helpful to expand the way that we lead our math classrooms.

Network data shows that this teacher built the most connections outside of the network meetings, tapping into these different perspectives, digging deeply into others' experiences, and benefitting from their feedback.

Teachers were most enthusiastic about opportunities to do work and collaborate directly with colleagues during these face-to-face meetings. They preferred collaborative working sessions to more didactic portions of meetings where new content was introduced. In particular, teachers enjoyed doing mathematics together and learning new teaching approaches. But overall, the network meetings were a feature of participation in the network that most teachers reported had great value.

Figure 2.1: Utility of Network Activities

Teachers found the **in-person network meetings** to be the most useful network activity



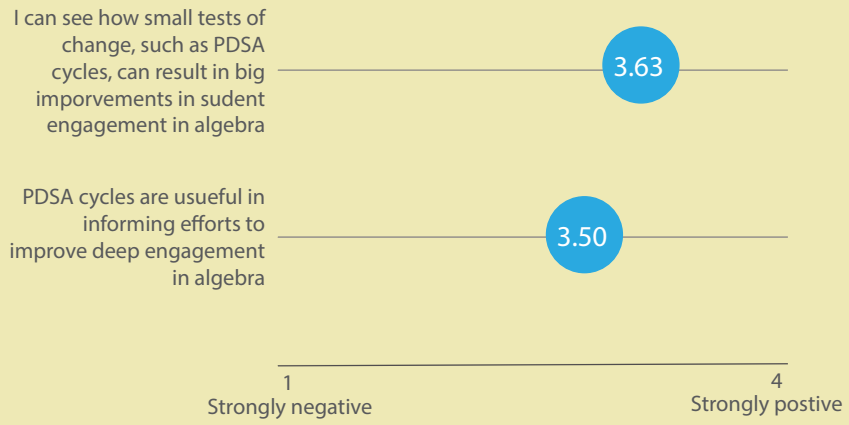
Inquiry cycles during action periods

During the time between network meetings, or "action periods," teachers were charged with identifying and testing concrete ways to make their Algebra I classes more student centered. They were trained in the face-to-face network meetings to utilize an inquiry routine called the Plan-Do-Study-Act cycle. The logic of the cycle is that teachers learn how to improve their practice by planning a specific change tied to a working theory of improvement, testing the change, studying evidence to assess whether the change constituted an improvement, and deciding what action to take in light of what was learned. The network created the expectation that teachers would engage in a series of PDSA cycles during each action period and document their learning utilizing a common PDSA form.

Teachers expressed a high level of enthusiasm about the use of PDSA cycles to improve their classroom practice.

Figure 2.2: Teacher Enthusiasm About PDSA Cycles

Teachers are enthusiastic about the use of PDSA cycles to improve their practice



One common challenge that emerged with the PDSA cycles was the expectation that teachers document each cycle using a common format. Documentation of PDSA cycles is important for two reasons. First, it helps professionals new to improvement work document each step of the cycle in order to internalize the systematic nature of the process. Additionally, it is important for the network's broader learning agenda that teachers are documenting what they tested and what they learned from cycles, so that network leaders can consolidate and share this learning—a function that separates networked improvement communities from traditional collaboration spaces.

Some teachers struggled with the documentation demands, perhaps because writing about teaching practice is not a typical component of teachers' work.

> *Paperwork is not my strong point. … That kind of housekeeping stuff is really hard for me. I love teaching and I love everything about it and I love planning and I love being with the kids but when it comes to things like, I need to give this survey or write down these things—I get too in the moment. And so that is the hardest part for me—which doesn't make it a bad thing. We're going to understand why this is important it's just – it was the hardest thing for me for sure.*

> *I document in different ways. I fill out the template prior to any interaction I have with the network to show that work. I mean I have it sort of in my mind and that's what I do. I'm a much, much looser thinker. … I feel a little bit restricted by the rigidity of that form.*

Virtual meetings to support inquiry cycles

To support teacher engagement and promote social learning, the network also organized virtual meetings of two to three teachers plus a network leader focused on planning and debriefing inquiry cycles. These monthly meetings provided a forum for teachers to identify aspects of their teaching practice to target for improvement, generate potential change ideas to test, and discuss the results of these inquiry cycles. In these meetings, teachers had the opportunity to dig into specific instructional challenges and ways to improve with teachers teaching the same Algebra I content and a Hub lead with research and practical expertise in mathematics pedagogy and improvement science.

One teacher reflected on how the Hub lead supported his learning in a virtual meeting,

> *I remember one instance when I was working with my Hub coach and my teacher partner. I was actually questioning my change idea in that I was looking at how to increase communication skills amongst students when talking about mathematics. It struck me that a little side technique that I was doing to practice for a test was generating results that I thought were very, very positive, and it was completely separate from my PDSA cycle. But my Hub coach embraced it and had me tease out what factors were working and why did I find it important, and it's actually going to be my next area of focus for the next run of my network's work for this coming year. So that, to me, was amazing, because it had little to do with what the PDSA challenge I was talking about at the moment, but my coach had enough insight and guidance to say, "Well, don't just toss that aside, that little voice that you have. That could be very, very useful." I took a lot out from that particular instance.*

Groups typically were composed of teachers working to address a common aspect of the network's working theory of improvement. For example, some groups were focused on how to support students in justifying their mathematical solutions and explanations. In general, we found that groups with a high level of joint enterprise seemed to have richer conversations and produced more insights about how to make their classrooms more student centered. This sense of a joint enterprise was created when teachers tested a common procedure or instructional routine, or used common measures to assess whether the changes they introduced led to improvement in practice. For example, three teachers who focused on providing students with more opportunities to make connections spent a large part of the year generating, testing, and refining a routine for exit tickets, an instructional strategy often used at the end of a class period to check for student understanding. While each teacher used the exit ticket for a different purpose, they used a common rubric to assess impact and taught students of a similar demographic.

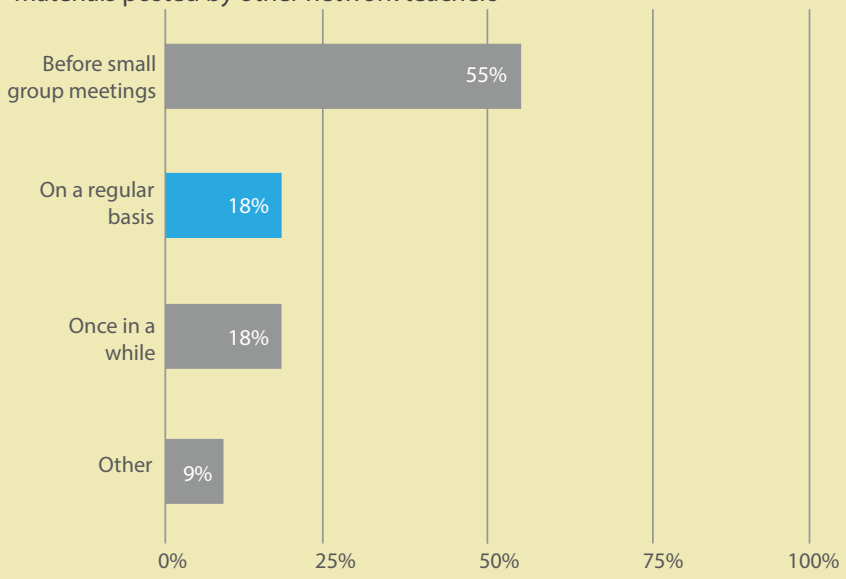
> *I did a lot of learning from others in my small group. I was in a group [where] we were all focused on trying to use exit tickets. We all implemented them quite differently. So, I think that thinking about different ways you have students participating at the end of class—because learning about the challenges of other teachers and their students was very interesting to me.*
>
> *We would each try implementing our exit tickets twice a week for three weeks, and then we would talk about the data points that we collected which were all different, although we used the same rubric. Then talk about what were the successes and challenges, so I think it was a shared experience with a lot of variation.*

Emergent informal interaction

Finally, the network has taken initial steps to seed and promote continued informal interaction among teachers outside of designed participation structures. Through joint work and social events at face-to-face network meetings, some teachers have made connections with other network teachers that extend beyond formal meetings. For example, a teacher in Vermont used a professional development day to travel to another teacher's school and have an extended collaboration session to learn more about an instructional routine she wanted to implement in her classroom. Additionally, the network maintains a curated Google Drive system where teachers post resources and artifacts from their inquiry cycles. While not a widespread current practice, a few teachers reported regularly reviewing materials posted by other teachers in the Google Drive. See Figure 2.3.

Figure 2.3: Viewing of Other Network Member Materials

While not widespread, some teachers report **regularly viewing** materials posted by other network teachers



One teacher explained how the Google Drive helped him find ideas and resources to solve his challenges:

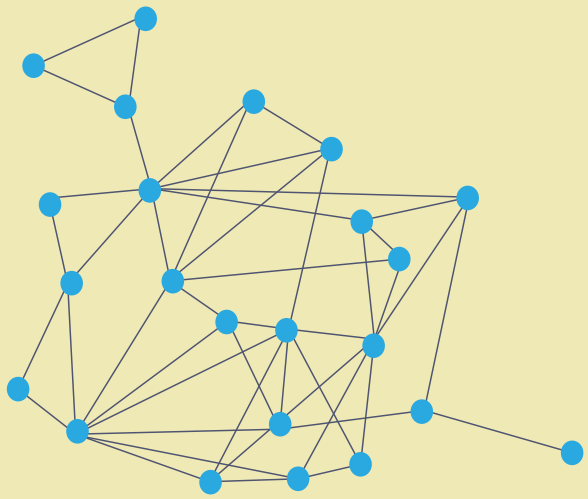
> *Well, I hop on the Google docs and reach out to some people, every once in a while, because, you know, when I'm having a hard time introducing material or having a hard time with a particular unit, I usually hop on the Google docs to see if anybody has done something, if they had a change idea or some resources they shared in that folder, then that's been helpful. I will connect directly with teachers if I have questions or I need clarification on some of the stuff that they did.*

In sum, BMTN has created multiple modes of participation enabling complementary learning and development opportunities for network members.

The following network map (Figure 2.4) illustrates the emerging network of connections among BMTN teachers that occur outside of formal participation structures. The map reveals that 21 out of 23 teachers reported interacting with at least one colleague outside of network meetings, with an average of three reported connections with colleagues through informal interactions.

Figure 2.4: Outside of Network Meeting Interaction

Most teachers interact with at least one other network teacher outside of formal network meetings



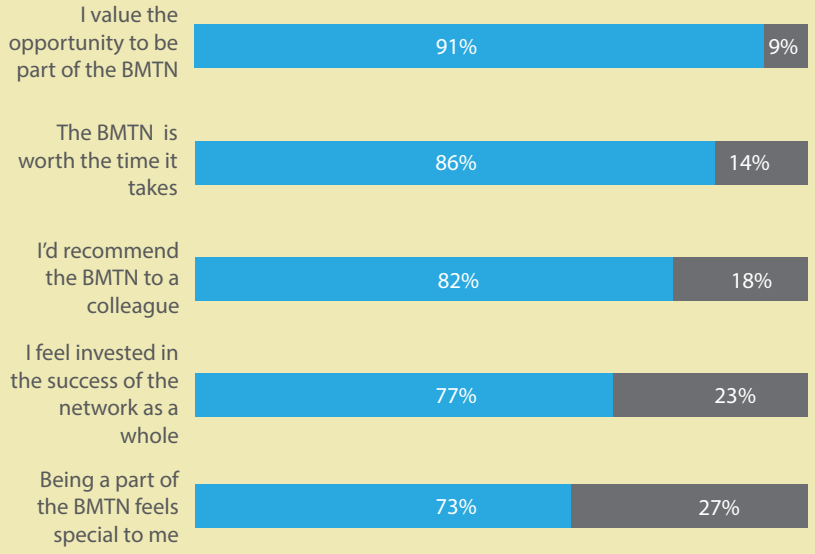
Teachers universally valued participation in the network

In surveys and interviews, teachers expressed very high levels of enthusiasm for participation in the Better Math Teaching Network. In interviews teachers made comments such as, "It was such meaningful work, " and "It was definitely worthwhile."

In a series of survey items about the value of participation in the network, all respondents agreed or strongly agreed with statements such as, "I value the opportunity to be part of the BMTN," and "The BMTN is worth the time it takes." Within the universal agreement, most chose the most intensive "strongly agree" indicating very high value in the network. See Figure 2.5.

Figure 2.5: Value in Network Participation

The majority of teachers **strongly agree** there is value in participation in the network



Interviews with teachers surfaced four inter-related themes about what they valued in the network:

- The network provides an opportunity for productive collaboration with colleagues teaching the same course and grappling with similar problems of practice—this is a group passionate about mathematics instruction and they valued a community of like-minded teachers.
- The network provides (formally and informally) teachers with access to helpful resources, such as books and subscriptions, websites with quality tasks and visualization tools, math tasks for specific content, classroom activities and routines, and teaching strategies.
- The network provides teachers with opportunities to learn and develop their practice, which in turn leads to improvements in teaching and student learning or engagement. Teachers valued the network as a vehicle for professional learning, often more valuable than the professional learning opportunities provided in their local contexts. In many cases, teachers reported limited to no access to professional development targeting mathematics instruction in their schools and districts.
- Teachers feel a sense of pride and professionalism through their participation in the network.

I generally don't like professional development, so I guess that's part of why I was willing to do more because I was enjoying the work that I was doing and I felt like it was really benefitting me as a teacher.

One thing that makes me really proud of this [network] is that you are made to feel like a professional. And that you're really important.

The other really nice thing [about being in the BMTN] is being treated like a professional, being part of a professional group. … Teachers don't get that very often in the world, and there really is something to it, to be treated like a professional.

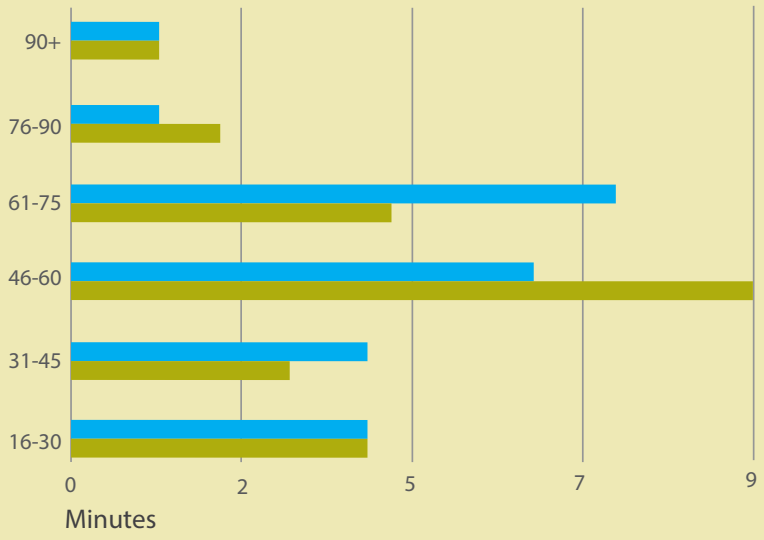
In general, there is promising evidence emerging from BMTN that a networked improvement community focused on improving classroom instruction can be a productive vehicle for robust professional learning and development, collaboration with colleagues, and bolstering teachers' sense of professionalism.

Participation levels varied across time and teachers

While teachers universally valued participation in the network, we saw differences in the intensity and form of participation across the 23 teachers and over time. For example, teachers reported a significant amount of variation in the amount of time they spend on work related to BMTN in an average week, as reflected in Figure 6. Some teachers reported spending less than half an hour on BMTN-related work while others reported spending over 90 minutes. The majority of teachers reported spending between 45-75 minutes on BMTN work, with the modal response for time spent higher at mid-year than at end-of-year. Interviews with teachers suggest that they reduced time allocation in the second half of the year due to additional competing demands that come after the winter break. Consequently, intensity of participation was influenced by the time of the school year.

Figure 2.6: Time Spent on BMTN Related Work

The modal response for time spent on BMTN related work was higher at **mid-year** than **end-of-year**



Time commitment to the network was important because it was associated with the degree to which teachers leveraged the resources available through network participation. For example, the teacher who reported spending 90 or more minutes in an average week on network related activities also reported regularly reading what other teachers uploaded to the shared Google Drive folder. In contrast, a teacher who reported spending on average 46–60 minutes per week reflected on her participation saying, "I feel I don't use the network, at least when I compare to others, as much as others do. I'm doing the work in the classroom on a regular basis, but I don't feel like I'm accessing the network outside of our meetings."

We further examined participation in the network by examining whether teachers met the expectations for participation set by network leaders, including meeting attendance, completion of inquiry cycles, and production of documentation related to inquiry cycles. The clear majority of teachers met or exceeded the expectations for participation promoted by the network: 20 out of 23 or 86 percent.

The three teachers who did not meet network expectations for participation were more likely to report specific challenges associated with participation in the network. In December, the lower participation teachers were more likely to report that time required for participation in network meetings and time spent doing PDSA inquiry cycles were challenging or very challenging, although their perception of this challenge diminished over time. These teachers were also more likely to report that integrating the BMTN work with the curriculum of their school was a challenge.

Conclusion

The Better Math Teaching Network created a multifaceted approach to fostering teacher participation in the network. Teachers had scaffolded opportunities to utilize improvement science methods to learn how to make their Algebra I classrooms more student centered. Additionally, participation structures created opportunities for social support from colleagues teaching Algebra I beyond their local teaching context. In general, this mix of participation structures was highly valued by teachers and spurred high levels of participation in the network.

Chapter 3:

Integrating Improvement Science Into Practice

One of the goals of the Better Math Teaching Network is to help high school algebra teachers understand and infuse improvement science principles into the core of their professional practice as a mechanism for using more student-centered instructional approaches in mathematics. Unlike many other education improvement initiatives in which teachers are supported to adopt a specific pedagogical technique, utilize a particular set of curricular materials, or deepen their content knowledge, the goal in this endeavor is to infuse a generative and disciplined professional inquiry practice that could later be applied across content, pedagogical approach, and/or curricular materials.

Our developmental evaluation sought to identify the opportunities and challenges associated with teachers' efforts to understand and integrate improvement science principles into their daily work. Primarily explored through teacher interviews, surveys, and case studies, this chart essay summarizes what we have learned so far about conditions that support or hinder teachers' efforts to infuse improvement science into their professional practice.

Opportunities and Key Supports

The Hub has built a support routine around teachers' enactment of repeated Plan-Do-Study-Act cycles

The Hub network leadership team has developed both tools and routines to support the design and implementation of each PDSA cycle[5]. Tools such as driver diagrams, process maps, and PDSA templates are intended to provide anchors for teachers' conceptual and practical work. Routines such as sequential and carefully timed whole-network meetings, small-group works, and coaching sessions are intended to create conditions for collaboration, constructive feedback, and sense-making. In the first formal year of work, the Hub leaders were accessible to members and offered detailed feedback to sharpen, refine, and/or deepen PDSAs as they were developed. Teachers used these tools and routines to build carefully identified change ideas[6]. The coaching support is particularly valued by network participants and is viewed as critical for narrowing the focus of the PDSA, validating the work, encouraging persistence in the face of challenges, and highlighting hidden successes. The focus of coaching was often on identifying or narrowing a change idea, linking the change idea to the DEAs, figuring out how to measure outcomes, and analyzing and interpreting data.

> *We don't always have to reach some specific end goal, but whatever we're doing that's better than we did before is great news.*

In addition to the tools and routines, the Hub's design of having teachers engage in repeated cycles of PDSA in a single year helped provide the repetition needed to try and become comfortable with the PSDA process and improvement science principles. Understanding and using improvement science can be challenging, and so it is important and powerful for participants to experience multiple iterations, with guidance from someone with expertise.

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[5] Plan-Do-Study-Act, or PDSA, cycles are an inquiry routine used in improvement science. The logic of the cycle is that teachers learn how to improve their practice by planning a specific change tied to a working theory of improvement, testing the change, studying evidence to assess whether the change constituted an improvement, and deciding what action to take in light of what was learned.

[6] Change idea is a term from improvement science that is defined as "an alteration to a system or process that is to be tested through a PDSA cycle to examine its efficacy in improving some driver in the working theory of improvement" (Bryk et al, 2015). In the context of BMTN, a change idea is a small change to planning or instruction that a teacher makes in order to examine its efficacy in improving deep student engagement in algebra.

You're not always going to get there in one year or one cycle. This is not going to be this magic thing.

Repeated iterations also are viewed as a means to integrate this new routine into teachers' regular practice so that it becomes the way they do their work, rather than an add on.

My first PDSA cycle was helpful in the fact that I knew—by the time I was done with my first group I knew what I was doing so that when I got to working with [my second group] the PDSA cycle wasn't the thing that I was most focused on. I was most focused on the change idea, and other things. I didn't have to worry about the process because I knew the process now.

The PDSA cycles were a routine that helped teachers slow down their practice and be more reflective:

I think through the intention of what this process is with the PDSA cycle and collecting the data—not only, one, does it slow me down, but it helps me to digest exactly what is going on.

The collaborative space is seen by network participants as powerful for supporting their professional learning

Participants universally valued the collaborative spaces created within the network. The collaboration was particularly helpful for learning improvement science as members grappled together with the nature and grain size of change ideas, how one might measure the goal, and how to make sense of the findings. Participants felt that being in meetings with the whole network, where there is more variation in teachers' background and change ideas, offers a chance to have broad exposure to possibilities and observe the range of approaches. Some teachers reported that the exposure helped inspire them for their next change idea.

It was really cool to see what others were doing and think about my next possible change idea.

Honestly, the second biggest learning I had from the network was at our final meeting, when we all got to share our final write-ups for our PDSA cycles. I really got to see what the other network members were doing, what some of their great outcomes were, and some of the strategies that they used. I already have some new ideas of easy routines that I could put into place.

Work in smaller groups served to help some teachers focus more specifically on the change sought and drill deeper into their planning for intervention and measurement. Having the reflective conversations in which others query your plans and approach brought clarity to some as they struggled to define, justify, and measure their change idea.

[Another benefit is] the feedback we get from our colleagues when we talk about how things are going and what we're doing. In the virtual meetings, just having that time to sit and process the results of what's going on, and how people ask questions and listen to the successes that they've had.

When I was able to meet with the small team and have work time devoted to thinking about our PDSA cycle and what our change ideas might be, having those other people to bounce ideas off right there was really helpful to me.

The Hub made a deliberate choice to integrate the mathematics content with the improvement science

The BMTN Hub has effectively balanced improvement science and math content. They approached the work in an integrated fashion; that is, all aspects of improvement science are embedded within the mathematics goals. In their design, the Hub has intentionally and specifically framed the improvement work for teachers to be content specific and focused in these ways:

- They have defined the network's aim as increased opportunities to engage students deeply in algebra.
- They have clearly articulated what deep engagement in algebra means, through specific mathematical practices (justify, connect, solve).
- They have designed sessions for the network to collaboratively define what quality looks like in high school algebra in these three focal areas.
- They have staffed their coaching roles with individuals who are math experts, former math teachers, and also trained in improvement science (rather than having improvement science coaches with math experts only available from time to time).

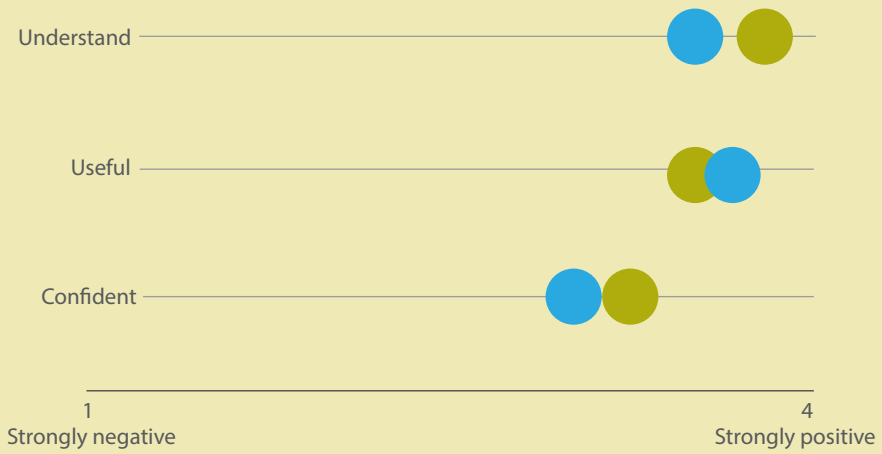
Most network teachers agreed or strongly agreed that they understand the PDSA cycle, are confident in its potential to improve practice, and see the process as useful

Among network participants, there is a high level of buy-in for the use of PDSA cycles and most feel that they have what they need to put improvement science to work

Most network teachers agreed or strongly agreed that they understand the PDSA cycle, are confident in its potential to improve practice, and see the process as useful. The cycle itself is somewhat intuitive for many teachers in that it roughly aligns with the instructional planning process, although the planning process has less formal or disciplined measurement than a PDSA. Our data suggests that self-reported understanding of the process and teachers' confidence that the PDSA cycle can help them achieve the network aims are both higher in the second year of participation than in the first, suggesting that practice and experience are important. See Figure 3.1.

Figure 3.1: Understanding and Confidence in PDSA Cycle

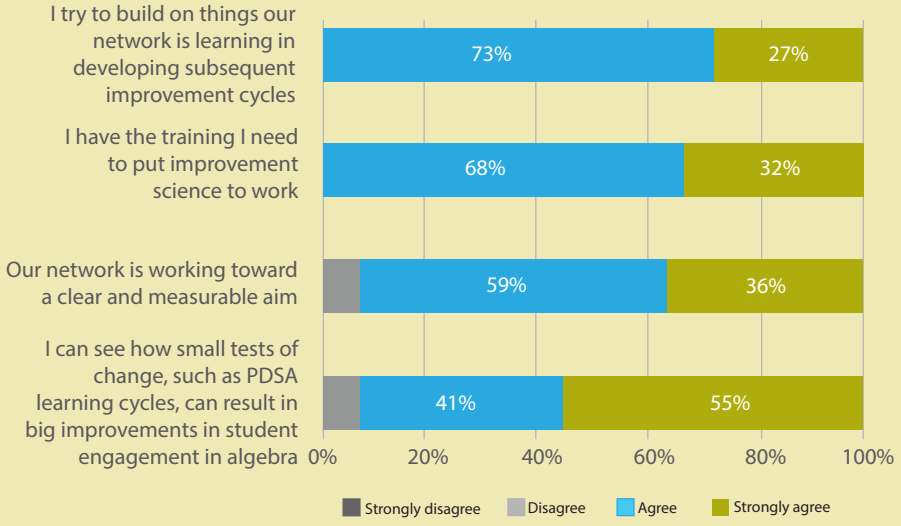
The means of self-reported understanding and confidence of the PDSA cycle tend to be lower for those in their **first year** than in the **second year**



More broadly, there is strong agreement that PDSA cycles can result in big improvements and that members are able to put improvement science principles into practice. See Figure 3.2.

Figure 3.2: Improvement Science and Improvement in Student Engagment

Teachers **agree** that improvement science can make big improvements in student engagement and they have the training to implement



Teachers are finding it valuable to connect PDSA cycles over time, both their cycles and with other network members

Teachers reflected on how their PDSA topics fit with their group members' topics and how their own topics related to one another over time. They reported that having shared focus with group members and sticking with a topic over time produces the most value because you can go deeper into the work and can share the work more easily.

> *I think it's easier if you choose one project and kind of stick with it as opposed to maybe what I did—which was have a couple of different projects throughout the year. You can focus better if you just stick with one project.*

> *That we focused on the same thing and had that sort of frame of reference for our conversations every time I think was really helpful.*

> *I felt better with that [focus] because we worked on it for a long chunk of time, so there were more opportunities to kind of revise the change idea and think about what I was measuring and how it was going. And I talked about it in my small groups, and it's like that was the one that I had more of a focus on.*

Understanding and utilizing improvement science is a complex endeavor and so difficulties and barriers are to be expected.

Challenges

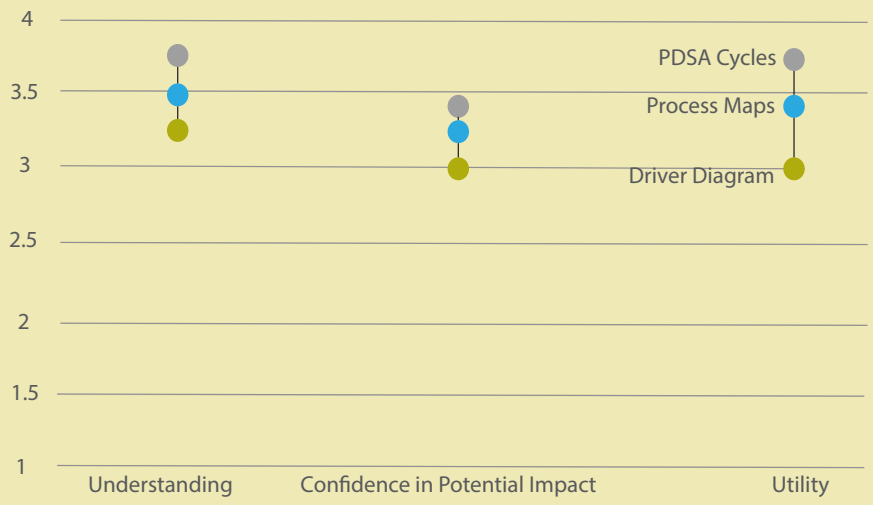
In this section, we highlight some of the tensions and challenges that have emerged as teachers try to integrate improvement science into their professional practice. Understanding and utilizing improvement science is a complex endeavor and so difficulties and barriers are to be expected. This evaluation was designed to seek these out and understand them so that the network may respond. Additionally, understanding and anticipating these challenges may help other educators and educational leaders who are using improvement science methods.

Teachers' understanding and perceived utility of improvement science tools is variable

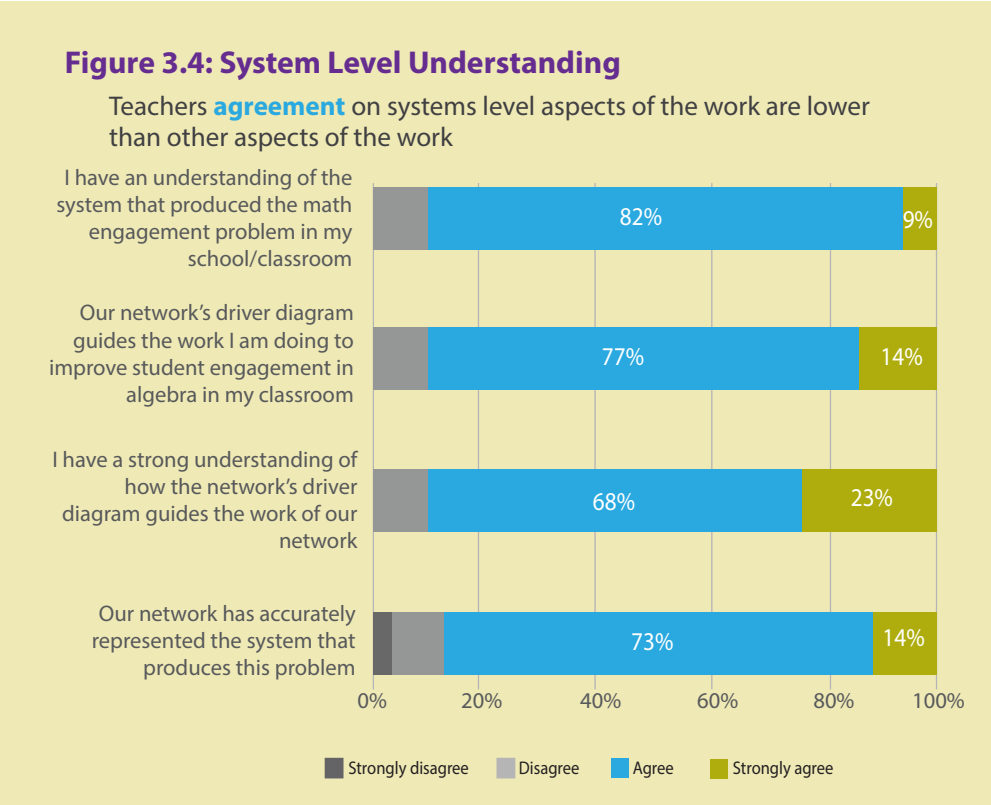
While most network members have expressed an understanding of PDSA cycles and see them as useful, the aspects of improvement science that are tied to the systems and conceptual representations are less universally understood, as reflected in Figure 3.3.

Figure 3.3: Perceptions of Improvement Science Tools

Driver diagrams are least understood and valued of the key improvement science tools



Of the key improvement science tools, driver diagrams are the least understood and valued among network members at this stage. The driver diagram represents a NIC working theory of improvement and serves to coordinate the work that members are doing to address different aspects of the problem of practice. The driver diagram may be less understood by BMTN teachers at this stage of the network's development because the network is focusing all work on one driver: making classroom instruction more engaging. A deeper look suggests that the systems level aspects of the work may not be as accessible to participants as the PDSA cycle in the early stages of involvement. Figure 3.4 shows small, but consistent levels of disagreement and lower intensity of agreement with items associated with root causes and systems-level understanding of the work.



While the process maps are less utilized and less valued than the PDSA cycles, several teachers found this tool to be highly useful. In one case, a teacher created a process map representing one of her key classroom routines, then sat with another BMTN colleague and their literacy coach, and together deeply explored the steps that she had in place to support student reasoning and the steps that were missing. In this collaborative activity, the teacher was able to identify where in her routine she wanted to focus her improvement efforts. Using the process map in this way helped her better understand her own classroom practice and identify change ideas for future use. It was such a successful activity that she and her colleague shared it with their 11th- and 12th-grade professional learning group, and presented it to other math teachers at a local conference.

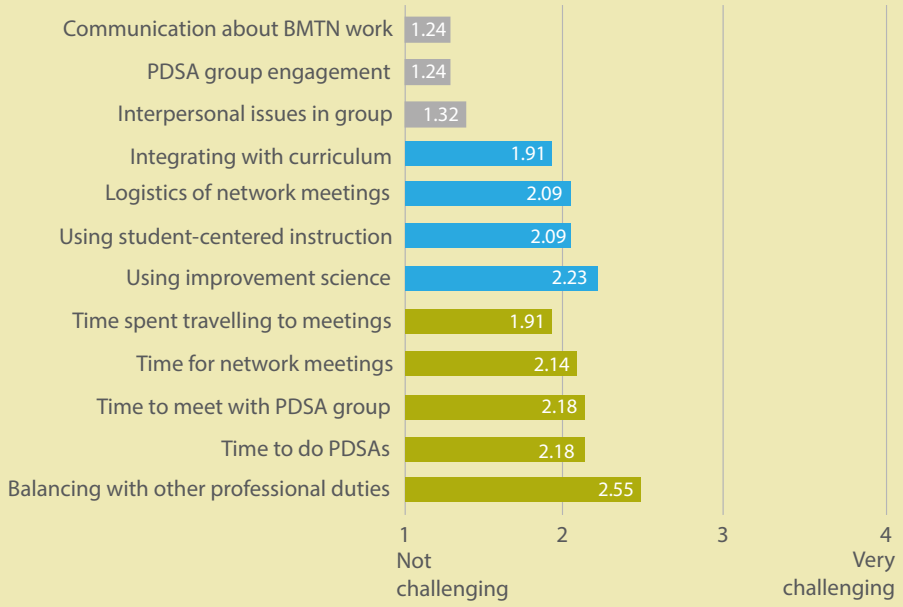
Interestingly, while most teachers reported strong understanding and commitment to the improvement science approach, several network teachers have wondered whether small tests of change really do what is required to reach the goal of student-centered learning. In one conversation, a teacher reflected, "I wonder about this 'start small' part. Do you really just change one small thing about your practice or do you blow the whole thing up?" She went on to talk about how student-centered learning requires transformative change and wondered whether small changes would be sufficient to achieve this goal. This suggests that even though teachers have generally embraced key ideas in the improvement science approach, there may be some healthy skepticism as teachers see what kinds of results the network can achieve.

Figuring out how to fit in the demands of the work within existing professional commitments is a significant challenge

At a broad level, participation in the network can be challenging due to the time needed to engage in the work. The chart below shows the mean level of agreement (4-point scale from "1-not challenging" to "4-very challenging") in June 2017 on a range of potential challenges. One of the most significant challenges is for participants to find the time for the collaboration and use of the PDSA model balanced with their other professional duties. In addition, the technical aspects of using improvement science also surface as a significant challenge at this stage of the work, which will be further discussed in the next section.

Figure 3.5: Challenges of Improvement Science

Time and **technical** aspects of improvement science are the most signifigant challenges for network members



Network members reported that it is difficult to balance the demands of this work with their other professional duties, conduct the PDSAs, meet with their small groups and attend network meetings.

> *Thinking about them, and planning for them, and coming up with a new change idea, and working with someone else, just finding time in everyone's schedule to meet, whether it's with the Hub leader and my BMTN colleague, or just my BMTN colleague, all those things just seem to take more time than you had originally thought.*

> *I think finding the time to just do it has been the biggest challenge. After having class, I remember saying, 'Oh yeah, I have to go and look at those exit cards, and tally them for this particular thing.' That has been challenging.*

Although each stage of the PDSA cycle has its own challenges, measurement is the most persistently problematic for teachers

In this network, improvement science principles are taken up through a routine of regular PDSA cycles. As network members worked to implement several inquiry cycles during the school year, we studied
their PDSA documentation and interviewed teachers about their experiences with the process.

At a broad level, several challenges to utilizing the PDSA model were communicated by teachers:

- Negotiating the alignment of the change idea to classroom needs, the network overall, and their PDSA group specifically
- Documenting the work given the fast pace of teachers' work and the perceived complexity of the sharing formats

Teachers also reported specific challenges within each stage of the Plan-Do-Study-Act cycle, which are highlighted in the table below.

Table 1: PDSA cycle challenges

Stage	Challenge
PLAN	• Identifying quality measures • Scoping the change idea to the right grain size • Having enough collaborative planning time with small group • Identifying the right data to collect in advance so that data collection in the moment is not overwhelming
DO	• Collecting data within the pace of teaching • dapting to unpredictable school schedule changes • Documenting while implementing
STUDY	• Making sense of the data (organizing it, evaluating quality, aligning with guiding questions in the PDSA) • Conceptualizing the work given its sheer complexity (e.g., the task matters, data changes with quality of the task so how to compare across different tasks) • Keeping up with timelines
ACT	• Ensuring that the decisions at this stage are grounded in the data and not just intuitive or informal reactions • Navigating the structural challenges that are implicated in this stage

Of all these challenges within the PDSA cycle, measurement was the most persistent and widespread.

> *I also feel like I don't have the best or most efficient tools to do that yet. I guess that comes back to the measures piece, and that's an area that I would like to improve on more this year or get more support with. I worked on justify. What I ultimately ended up using quite a bit was those quality criteria that we established as a network for justifications…. One of the things that's great about the network right now is that we're getting to do things that we see as challenges in our classroom, and try to develop approaches to improve those areas. I think that's the whole idea with the change idea map and the fact that all these ideas are coming from teachers on the ground level. But I think an area where maybe we could use a little more direct guidance is what those measures, maybe not what the measures are, but the tools for assessing the stuff we get from students. Like, here's an example of a rubric that we've created from our quality criteria that maybe we could all use because if we're all trying to work towards these same aims, then do we have a rubric or scale that we can all use or adapt or draw from when we're trying to measure quality, instead of each one of us coming up with our own tools for measuring quality?*

One pattern that emerged in observations and case studies was a tendency of network members to seek quantitative measures only, and disregard or dismiss qualitative measures. Interestingly, in the analysis of PDSAs that the evaluation team conducted, the content in teachers' act phase was often disconnected from the data that had been collected, and, instead, appeared to be more grounded in intuition or informal teacher reactions. As one teacher shared:

> *I think doing that PDSA cycle and listening to those audio recordings didn't actually inform whether I was going to continue that practice or not…. It felt successful and effective as we were doing it in the moment. I didn't need to fill in a data chart to do that. Now, I know they've been really pushing to start talking more about quality, so I suppose if I was really going to emphasize that quality piece, the listening in more detail to what kind of justifications they were giving could be of use to try to push me in that direction.*

This finding might be attributable to a lack of alignment of the measures with the outcomes teachers believe matter, a lack of faith in the quality of the measures used, or a previously unfamiliar practice that will take time to embed in teachers' work. While the BMTN Hub has provided intensive PDSA coaching to support the understanding and uptake of the approach, these responses suggest this is an area for ongoing support and development.

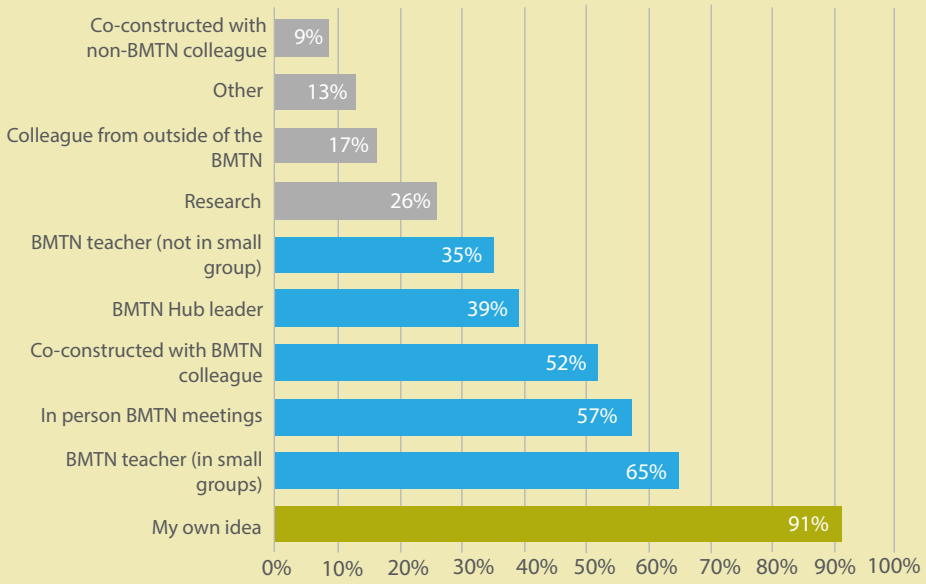
There is a tension in how much expertise from research and instructional models should be injected into the work versus teachers' own discovery and invention

A hallmark of the improvement science work is to tap in to practitioners' own change theories so that they have ownership over the innovation being tested. To this end, the network has created spaces that are driven heavily by teacher invention in collaboration with colleagues. On a few issues, however, some network teachers express a wish to have more input from existing research, expertise, and/or tool repositories. These areas include the source of change ideas, especially with regard to expertise around student-centered learning and in the measurement aspect of the PDSA cycle.

Teachers reported the sources of their change ideas, and the vast majority came from their own ideas or in collaboration with BMTN leaders or colleagues. Only a small number were generated from research, non-BMTN teachers or other sources. Improvement science tends to emphasize a broader and more systematic search for change ideas including analysis of current practice, exploring positive deviants, research evidence, experts who have solved similar problems, learning from users, brainstorming, and the 90-day cycle (a quick research routine that scans the field broadly to identify specific change ideas). Figure 3.6 shows teachers' self-reported sources of change ideas on the June survey (they could select more than one source because they tested more than one change idea).

Figure 3.6: Change Idea Sources

Teachers are generating change ideas from **network** and non-network sources



These data suggest that the network is, indeed, serving as a collaborative space for idea generation and analysis of practice. However, one teacher noted that this reliance on network colleagues can be limiting, as illustrated in the following excerpt from a teacher interview:

> *I feel like it should be more than us just getting ideas from each other, or things we think would work. I would like to see more coming in from the outside, from people who are really good with this stuff. It could be people, it could be books, it could be videos, it could be speakers we have. But I feel like we should be getting more inspiration and vision from experts at this, or people who are more experienced at this. I feel like sometimes we're missing the big picture, and we don't have a common vision of the big picture. If you have a bunch of people who have taught in a traditional way, relatively traditional, trying to figure out how to do this, you might be making steps forward, but I just don't think it's going to be nearly as revolutionary as getting some outside inspiration.*

Similarly, for identifying and/or developing measures to use within PDSA cycles, about 80 percent of teachers reported building at least one instrument themselves. Others built or obtained measures mostly via interactions within the network. Only a handful reported drawing from research.

As with sources of change ideas, teachers mentioned that they see an opportunity for the network to take on a more active role in both tapping existing research and tool repositories, and to bring coherence across PDSAs regardless of specific change ideas.

Conclusion

As network teachers worked to understand and integrate improvement science principles into their practice, they drew on the power of the collaborative space and benefitted from the way the Hub situated the improvement science within the mathematics and pedagogical content of the aim. By the end of the first year of the network, most teachers valued the PDSA cycle as a means to improve student-centered learning practice and thought that the Hub's choice to build in iterative cycles was helpful in developing their skill at using the approach. They relied on these supports and experiences as they confronted the expected challenges of understanding the various improvement science tools, fitting the time to do the network activity into their existing professional demands, and measuring and documenting their PDSA work. Following how teachers respond to these challenges next year will help us understand the natural developmental process of learning to use improvement science to improve teaching.

Chapter 4:
School Context

Network teachers must enact their student-centered learning change ideas within their specific state, district, school and classroom contexts. We know from decades of research on a variety of education change efforts that contextual conditions at the state or local level can serve as powerful barriers and enablers to realizing desired outcomes. Such conditions include leadership understanding and instrumental support for the initiative, collaborative and problem-solving routines and spaces, compatibility of curriculum, levels of teacher autonomy, and alignment with accountability structures.

The Better Math Teaching Network's use of improvement science was intentionally designed to allow the work to be adaptable to contextual variations. The BMTN also chose its content focus strategically so that there would be a shared sense of value for the work. Algebra I is recognized almost universally as the gateway to postsecondary and career readiness, which helps ensure that the network is aligned with high value targets for schools and districts. These decisions help to insulate the work of the network from common tensions that arise when education change efforts are initiated outside of local contexts.

In this first year of the developmental evaluation, we sought to understand initial levels of leadership support and how teachers' work in the network interfaces with their school context. We draw on data from teacher interviews, case studies, and teacher surveys to report key themes that are emerging in the early phase of the network.

Current levels of network participation and change in teaching practice and student engagement with mathematics are being realized with general, but not strategic, support from building-level leadership

Network teachers reported that building administrators are either generally supportive of teachers' efforts to engage in the work of the BMTN or are largely unaware of the work. These teachers indicated that leadership allows them to leave the district for network meetings and engage in other network obligations as part of their professional development time, which is interpreted by teachers as "support." A small portion of teachers indicated that their principals are enthusiastic about the work because it is aligned with the principals' orientation toward a culture of improvement and continuous learning, even if the principal is not deeply engaged in the substance of the network aim.

> *They're very supportive but it's, like, 'Oh, you want to do this Better Math Network thing? Cool. Go do it.' Like, 'You're going to bring out—bring back new ideas and make us better. And we're into that.' But there's no one really, like, 'Oh, here's this cool opportunity related to math. You should try this and you should push this with your teachers.' I'm the one bringing the new ideas for math instruction to my department, I would say.*

Only a few BMTN teachers reported having school or district leaders who have more than a superficial understanding of the work. In at least one case, the principal invited her network teachers to share their work at a grade-level professional learning meeting. The response was so positive that several

non-network teachers in that school have begun to engage in process mapping their own classroom routines as a way to determine where to target their own improvement. The literacy coach is supporting teachers in the process. While she does not have content expertise for all the involved teachers, she is a respected school leader who knows how to ask good questions to help teachers identify student-centered classroom practices.

Teachers in contexts with scripted curricula reported less flexibility to engage in both the improvement science and student-centered learning aspects of the work

Alignment of the improvement work with curriculum has not been identified as a significant challenge for most teachers; for about one-quarter of the BMTN teachers, however, it is a moderate challenge. When teachers mentioned difficulty, it was typically associated with teachers' perceptions that the use of student-centered instructional strategies reduces how much "coverage" they can attain because they are spending time going deeper into the concepts. This is the classic tension of "depth vs. breadth."

> *I'd love to do it and I think my school supports me in my work that I'm doing with my network and would love me to be more student centered and all. But they don't seem to understand that that means that I can't get through as much work in order to do that.*

> *I've always been told I'm a traditional teacher and I kind of blame it on the sheer amount of content that I feel like I'm forced to get through in the short amount of time that I have. I don't always feel that I have the time for the projects or for the self-exploration and whatnot.*

> *It keeps pushing me to think of, I'm not just getting through content but what can students do with the content and why is it important for the students to even know what they know? There's some tension there as a practitioner.*

> *If we define Algebra II as covering these 12 topics, then the way we have students engaged in thinking about ideas is a detriment to learning. If we define learning as truly understanding and making sense of things mathematically, and being able to put them in context and stick them in your brain long term, and adapt them and be flexible with them, critique them, then no. Understanding that you're going to cover less topics.*

Some teachers have scripted or extremely rigid curricula, which intensifies this "depth vs. breadth" tension. In one case, a BMTN teacher is expected to align her teaching with the other math teachers in her school, which includes using the same curricula (e.g., tasks, activities) and assessments within the same timeframe. Identifying targets for improvement work that fit within those constraints is much more difficult for her than for other network peers who have no set curricula or timetables to adhere to. A BMTN teacher who does not have rigid curricular parameters reflected on the constraints she observed in her network colleagues who do:

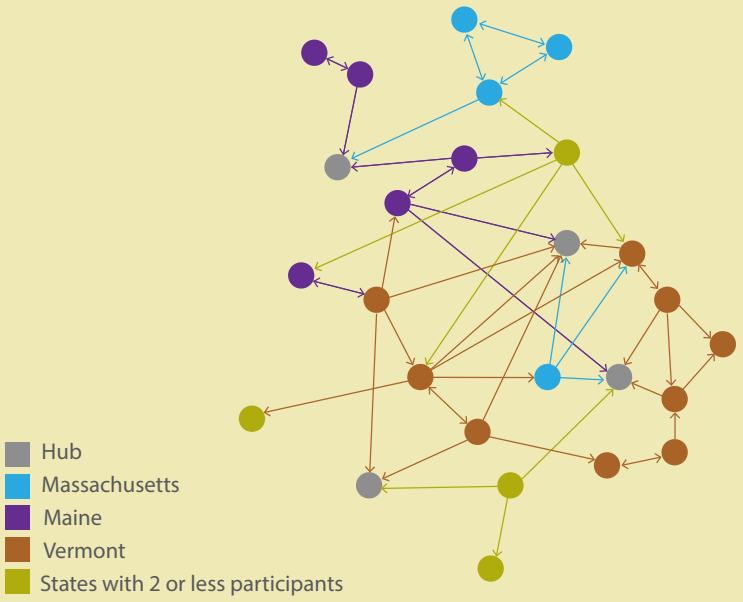
> *There are definitely people in this study who have extremely rigid programs. Extremely rigid. They can always move their classes to be more student centered, but I think it would be very*

difficult to get there authentically. So, I think if I was at another school and I came in and I found that it wasn't compatible with my district or it wasn't really working for me then I probably wouldn't have persisted. But if it had been working for me and I found the ideas invigorating then I would have.

State and local context is a powerful driver of voluntary teacher relationships within the network

Teachers' small working groups are constructed based on the substance of the change idea that they seek to test so that the group may engage in joint work. When we compare social network maps of these formal, structured relationships with maps of teacher-reported voluntary, informal relationships, we find that the teachers from the same state seek one another out. In Figure 4.1 we have mapped whom teachers reported going to for advice and support related to the network. Each teacher is color coded by his/her state, and we see that teachers within the same state are more likely to seek each other out related to their work with the network.

Figure 4.1: Teacher Connections By State



We hypothesize that this may occur both because of the common policy contexts that are shared by teachers working in the same state, a desire to have more face-to-face interactions without arduous travel, and potentially the similar student demographics that they share.

I think when I have the opportunity to meet face to face or virtually face to face with people, it's really helpful to have those conversations and they're definitely the things that keep the work going. I'm curious how we can make that happen more authentically, more easily, maybe, a little more locally sometimes. I went to [another school] and I met with [BMTN colleague] during our midterm week when I had a day without exams. My principal let—I'm like, 'Hey, can I take some professional time, go over there, I don't have exams.' She's like, 'Yeah, go.' So I met with [my BMTN colleague] one-on-one. And that was really helpful.

I would love to find a way to do some smaller in-person meetings that are less time. That would be a huge thing for me. What that does, it means that we'd have to be meeting with people only who are local to us, as opposed to people who live further away. There's a huge benefit to the whole group coming together, but for me, that in-person time is so valuable.

I would love to find a way for even some folks who I'm closer to, for us to just do a single day. Let's get together on this day, and take a professional day and meet, especially as the group gets bigger. If we're going to have 45 people in the group, a day when we can meet with 12 of us who are within maybe an hour radius might be really beneficial.

While all teachers reported benefits from participating in the network, teachers in isolated rural districts or resource-constrained districts reported the network provides critical supports

Teachers in remote, rural areas appreciate the access to resources the network provides that are generally not available in their local contexts. They reported having limited access to professional development and collaboration with local colleagues.

We're hours from a college. We don't have access to any other outside influences, and it would have been really easy to just come to work, do my job, grade papers, and go home, and not really think about, am I improving what I'm doing in the classroom?

I think we do a great job teaching, and our math department is excellent. It's probably the most functional department in the school, maybe the district. But I still have this fear of falling into a groupthink mentality because we are so isolated and cut off. Even if we're doing our own research, we're still collaborating with the same people.

About a third of BMTN teachers are either the only math teacher in their school, the only Algebra I teacher in their school, or have little connection with the math teachers in their schools. In general, all of these teachers engaged actively in their PDSA groups, and the majority of these more "locally isolated" teachers were highly connected to other network teachers.

I teach in a small rural school so there's not a ton of collaboration. I'm the only Algebra I teacher currently in our supervisory meeting. So it's nice to have the opportunity to work with other teachers who are facing the same challenges and working on the same content.

In some resource-poor areas (e.g., little to no money for professional development), access to the network is viewed as critical for stretching and growing practice.

> *I'm working in a rural school district that doesn't get a lot of professional development opportunities.*

> *I feel isolated being in a small math department. As a department, I get to work with the Algebra II teacher, the Geometry teacher and the Pre-Cal teacher, but I'm the only one who teaches my content, so it's kind of hard to get advice or see how they teach a specific skill or concept in their class, to get feedback, or collaborate with other teachers. We do not co-teach nor can we co-plan. So I've been kind of doing that on my own for the prior two years before joining the network.*

In most high schools, there may be an instructional coach or funding for professional development, but rarely is there a math coach and even more rarely do high school math teachers get content specific professional development. In some cases, principals and teachers see the network as a way to fill these gaps.

> *The people who have given me coaching focus on protocols and routines around classroom management. I do think this is very helpful, that it's good to get that feedback because that's transferrable to many different contexts, especially in the communities I'm from and want to work with. But I haven't gotten that, 'Was the task engaging enough? What could have caused the disengagement?' I haven't gotten that [math] coaching and that's what I need and want. So I say that because being part of the network I got a chance to talk with other teachers and see what they do. I'm like a kid in a candy store! I can ask all these other math teachers who teach algebra, 'How do you support students with negatives? How do you introduce stuff with polynomials that it's just numbers and letters? How do you apply it besides from a cheap word problem?'*

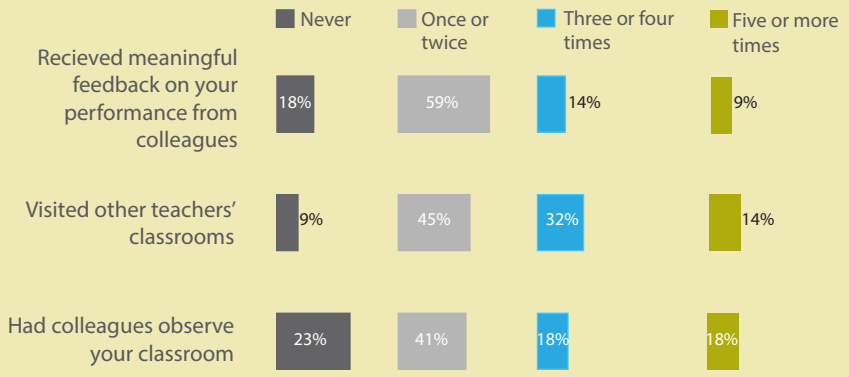
About half of BMTN members reported less than optimal professional learning cultures in their schools, reflecting an unmet professional need.

About 60 percent of BMTN members reported that most or all of their colleagues feel responsible to help each other be their best. This means that 40 percent of the network members teach in a less-than-supportive adult learning culture. In these spaces, access to engaged and supportive colleagues who are eager to help one another and to share their learning can go beyond filling instructional gaps to also providing the professional relationship and energy that helps sustain continuous improvement.

Fewer than half of BMTN teachers reported observing a colleague, being observed by a colleague, or receiving useful feedback on their teaching from a colleague more than once or twice in the last year, as reflected in Figure 4.2.

Figure 4.2: Teacher Interaction with School Colleagues

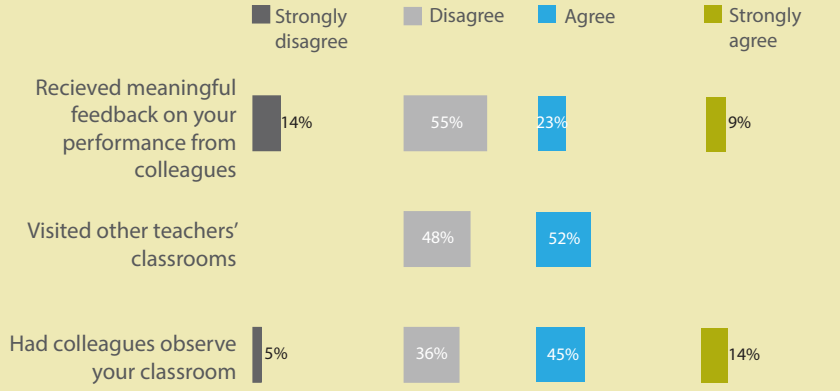
BMTN teachers' interactions with in-school colleagues about their practice are typically **infrequent**



For about half of BMTN teachers, their school contexts do not provide opportunities for deep and meaningful conversations about instruction and instructional challenges, as reflected in Figure 4.3.

Figure 4.3: Teacher In-School Opportunities for Conversation

BMTN teachers have **limited opportunities** in their schools for deep and meaningful conversations about instruction and instructional challenges



Taken together, this particular group of teachers is likely to benefit from a rich and robust network of like-minded teachers since they did not feel that they have a strong, supportive professional learning community in their school and district contexts.

Conclusion

Most network teachers reported general, but not strategic levels of building leadership support. This means that while teachers believed that they have the support of their leadership to engage in network activities, they did not see their own leaders incorporating the work into the strategic vision for the school. This is not surprising given that BMTN was designed as a network of teachers. Drawing school and district leaders into the work may be a future design consideration as the network plans for spreading its impact (see Laying the Groundwork for Spreading and Scaling the Network's Learning, page 102). Outside of leadership support, the nature of the mathematics curricula appears to enable or constrain teachers' efforts to engage in both improvement science and student-centered learning, with more scripted approaches increasing the challenges that teachers face in both areas.

Our first-year analyses also suggest that state and local context is a powerful driver of voluntary teacher relationships within the network with many more informal relationships clustering by state. In addition, we observed that some rural districts saw the network as a unique and powerful opportunity because they do not often have access to the caliber of resources that the network brought to bear.

Overall, it appears that the network has accurately identified its "target market" with about half of BMTN members reporting less than optimal professional learning cultures in their schools, reflecting an unmet professional need that the network appears poised to provide in its stead.

In addition to these high-level themes, we also suspect that some non-network initiatives occurring in some of the other schools or districts may align well with or be complementary to the NIC efforts. For example, in one district, a teacher reported that there is a strand of activity around the use of design thinking, which is compatible with improvement science approaches. Although this year's evaluation did not examine this issue closely, we plan to explore this further in the coming year as competing priorities are often a barrier to the take up of externally initiated work.

Chapter 5:
Influence on Teaching

The Better Math Teaching Network's focus on student-centered learning, and the aim of increasing engagement through opportunities for students to deeply engage in algebra, frame the work of network teachers. The network defines deep engagement in algebra as students are:

- Making connections among mathematical procedures,concepts, and application to real-world contexts, where appropriate (connect)
- Making sense of and solving challenging problems that extend beyond rote application of procedures (solve)
- Communicating and justifying their mathematical thinking as well as critiquing the reasoning of others (justify)

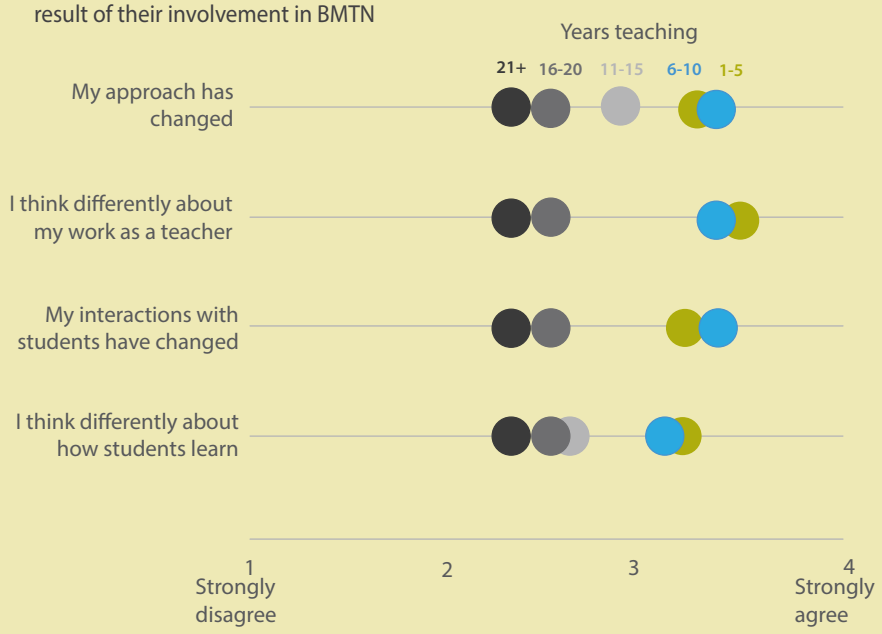
These three elements of deep engagement in algebra (connect, solve, and justify) are referred to by the BMTN as DEAs. The network uses improvement science to structure teachers' continuous improvement. In these ways, the design of the network is to change teacher practice in two distinct ways. First, the network aims to support teachers in making their Algebra I teaching more student centered. Additionally, the network aims to develop teacher capacity to be scholar-practitioners who engage in disciplined inquiry to address problems of practice.

Change in teacher practice is tethered to the network's foci

The majority of BMTN teachers reported that they have changed their practice as a result of their involvement in the network in at least one of several ways. In the June survey, 20 of 23 network teachers agreed or strongly agreed, "Since joining the network, my approach as a teacher has changed." See Figure 4.1. Not surprisingly, new teachers agreed more strongly with this statement than more experienced teachers.

Figure 5.1: Since Joining the Network, My Approach as a Teacher Has Changed

New teachers agree more strongly that their practice has changed as a result of their involvement in BMTN



As a result of their work in the network, teachers think their practice has changed in a variety of ways, including becoming scholar-practitioners and deeply engaging students in mathematics.

Becoming scholar-practitioners

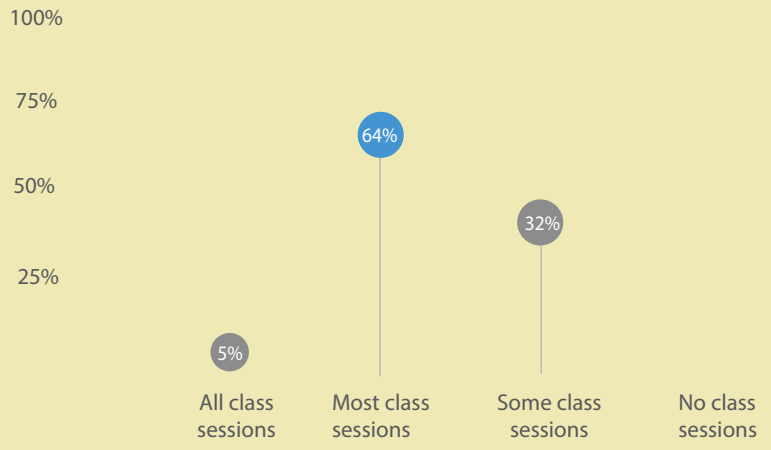
The network's workflow is organized around PDSA cycles. PDSA cycles are a routine used in improvement science to support continuous improvement. Teachers PLAN a small change to test in their classroom; enact, or DO, the change; STUDY the change by collecting and analyzing data specific to the change; and ACT by determining, based on what they have learned in the study phase, if they should adopt the change, adapt the change, or abandon the change. Based on this design, on a very practical level, improvement science frames the BMTN teachers' work. By engaging in scaffolded improvement work, we see several indicators that teachers are taking on the role of scholar-practitioner. Several teachers noted that the PDSA cycles allow them to stay focused on a change for a longer duration, and some teachers identified a shift in how they now use data to determine whether they will continue trying a new change idea. As one teacher reflected, "Why would you do anything in the classroom if it's not backed up by data, and why do you do a strategy if it's not working?" Another teacher shared, "[The PDSA cycle has made me] more reflective about my process, and [I] see what those baby steps are that I need to take along the way to get to this end goal. [It has] creeped into my practice." The opportunity to learn from failure that the PDSA invites is another way that at least one BMTN teacher changed her practice: "Improvement science has helped me to not feel like every new idea I have has to work the first time I do it."

Deeply engaging students in Algebra I

BMTN teachers targeted changes in their classrooms to be student centered and to focus on the three DEAs (the network's definition of deep engagement in algebra): connect, justify and solve. They sought to find ways for students to make connections themselves, justify their own thinking, and solve non-routine problems. Indeed, half of the network teachers said in June interviews that their practice has become more student centered as a result of their involvement with BMTN. In addition, teacher survey data reflects their perception that they do student-centered instruction often and it is tied to their PDSA work. BMTN teachers indicate that they were able to engage students in student-centered mathematics learning at least some of the time, with the majority of teachers saying they were able to do this in most class sessions. See Figure 4.2.

Figure 5.2: Frequency Teachers Engage Students in Student-Centered Learning

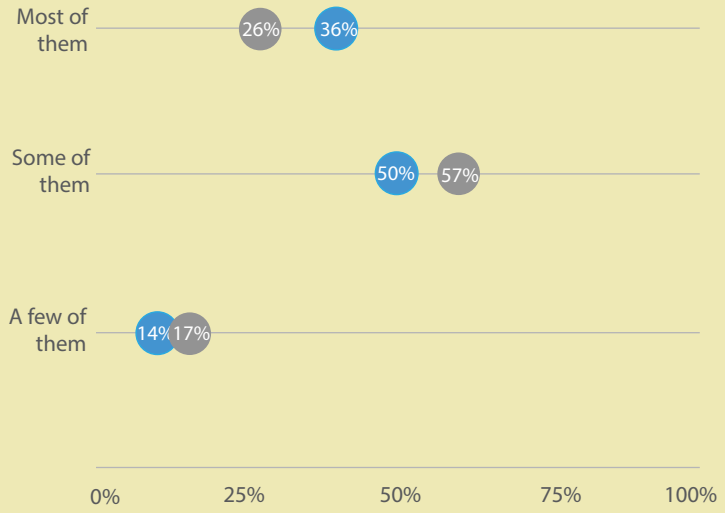
The majority of teachers indicate they are able to engage students in student-centered mathematics learning during **most class sessions**



Almost all BMTN teachers linked some or most of their student-centered learning opportunities to their PDSA cycles. See Figure 4.3.

Figure 5.3: Student-Centered Learning Opportunities Tied to PDSA Cycles

More teachers in **June** than **December** report most of their learning opportunites are directly tied to their PDSA cycles



In interviews, teachers noted changes they made in practice that echo tenants of student-centered instruction ("have students do more of the thinking"; "what are they going to be talking about? What are they going to be thinking about?"; "getting deeper understanding, understood how to collaborate with one another, what their roles were, getting them more involved in problem-solving").

Because teachers focused each of their PDSA cycles on one specific DEA (justify, connect, or solve), their chosen DEA framed the teachers' changes in practice. Throughout the year, teachers tested change ideas across the different DEAs, with justify being the most common. See Table 1.

Table 2: Change ideas tested, by element of deep engagement in algebra, in 2016–17

Deep engagement in algebra	Number of change ideas tested
Justify	37
Connect	15
Solve	15

Strategies to teach students to justify is the biggest network focus for instructional change tied to DEAs

Teachers chose to engage their students in justify more often than connect or solve. Thirty-seven of the 67 documented PDSA cycles focused on justify, and six of our seven case study teachers had at least one change idea in the justify element.

Teachers designed classroom activities that expected students to think, talk, and/or write about their justification. Examples include the following: role cards where every student in the small group had a discrete role, students partner and critique each other's work, or all students write a critique of a common problem. In some cases, teachers noted they were able to implement activities that asked students to justify their thinking or answer, and they saw results fast.

> *I had some very good success and I think my student engagement and student centeredness really increased with my PDSA for critiquing. I noticed it come out in conversations we'd have in class where students would follow up their sentence with 'I know this because,' … it wasn't me saying, 'Well, how do you know that? Could you tell us more?' They did it themselves. And then students were ready to say, 'I agree or I disagree.' Or they'd be listening and they're like—they'd have their hand up like, 'I want to disagree with that. I'm going to be patient, but I want to disagree with that.' And I saw that very quickly with my justify PDSA.*

A challenge that many teachers had with the justify DEA was how to measure it in order to know if the changes they were introducing were leading to improved student engagement. They asked questions like the following: What is a quality justification? How do I capture that when I am walking around from group to group? If I audiotape the small-group conversations, how do I assess the quality of the justification? Another challenge teachers faced with justify was how to support students to write quality justifications—often students could justify verbally but struggled to capture it in writing.

> *I need a way to get kids to justify better, and writing's not working because they don't want to write. They will, but I'm not getting quality responses.*

> *Our ninth-grade students don't necessarily come in knowing how to explain what they're thinking about math. I think they've been taught to show their work, but what I've found was that they have a really challenging time explaining. I was hoping that they would do it in writing, and I quickly learned that I had to stick to verbal just to get any quality responses.*

Supporting students to make their own connections

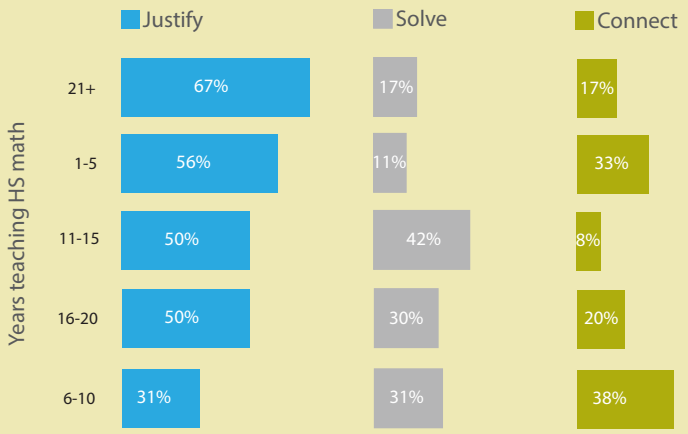
Half of the BMTN teachers chose to focus on the connect DEA at some point in the year, spanning both cohorts. Teachers changed their practice to structure opportunities for students to make connections on their own, or with each other, rather than the teacher explicitly telling students the connection. Teachers engaged students in making connections between prior learning and new learning; the math they were working on and real-world contexts; and linking procedures to procedures, concepts to concepts, and/or procedures to concepts.

Looking for problems that lend themselves to connections was a challenge for teachers, as was finding ways to measure the quality of a connection. They asked questions like the following: How do we know when a student made a connection between a procedure and a concept? How do you capture that? Two teachers who switched to a different DEA mid-cycle reported abandoning connect because they could not figure out how to measure it to their satisfaction.

More novice teachers chose connect than veteran teachers (8 of the 10 teachers who chose connect had taught high school math for ten or fewer years). See Figure 4.4.

Figure 5.4: Frequency of DEAs Used in PDSA Cycles During 2016-2017

The most frequently selected DEA was **Justify**



This suggests that novice teachers may be struggling with this aspect of deeper engagement in algebra more than their more experienced peers.

A different way to think about solve

When teachers gave students a chance to engage in the BMTN's DEA solve, they provided students with opportunities to solve math problems with multiple steps that took more than 20 minutes to solve. For traditional teachers, this was a very different way to think about what kinds of tasks and activities to structure. There was far more variability for solve across tenure categories than for connect and justify; primarily novice and mid-career teachers chose solve as their DEA.

Only seven teachers chose solve overall (it was the least frequently used DEA), and most of the solve PDSA cycles happened later in the year. In at least two cases, teachers chose to switch to solve because they realized from their student survey results that they were not providing these kinds

of solve opportunities. Other teachers took up the solve DEA after they found it difficult to have their students build quality justifications or make connections when they were working with simple problems that did not sustain student attention for more than a few minutes.

> *I couldn't have quality justification unless they were engaged in solving a rich task. Don't want to say it's assumed, but when we tried to do justify or connect, we weren't able to get justify when we did rote problems. We had to change our tasks to get at these things.*

Some challenges teachers faced who worked in the solve DEA were:

- Slow progress (saw less immediate results as compared to work in justify)
- Difficulty finding good tasks
- The realization that they had to go back and teach students problem-solving strategies
- The realization that they had to teach students how to persevere through tough problems (which gets into students' math mindset, a different primary driver)
- Challenges in measurement, which in some cases led to good change ideas:

> *As I went through them, every problem gave me completely different data because I was using so many different types of problems. But the first thing that I really noticed was no matter what type of problem I have, that the strategy was never good. That's what made me tweak to coming up with [this idea that] we really need to build out this strategy. We spent a long time that day coming up with strategies, and discussing them.*

Teacher practice is more intentional

Finally, teachers reported that participation in the network has made them more intentional in their instructional practice. One-third of the teachers interviewed gave specific examples of this.

> *I am more intentional about getting students involved.*

> *It's been interesting with the PDSA cycle because I feel like it's really allowed me to be way more reflective about my own process. …I think that some of the strategies that I'm trying are much more intentional to reach that end goal.*

> *I'm much more intentional about, 'Why are we doing this?'*

The PDSA cycles require teachers to test a change idea multiple times, and some teachers noted that this structured routine helped them stick with an idea for longer than they might have otherwise.

> *For me, what I've been doing, the best part about the PDSA cycle is just the accountability. I'm really making sure I follow through and try that idea.*

Teachers are making a shift from generic to content specific conceptualizations of student engagement

As we unpacked how teachers defined key components of the network's work, our data reflects (not surprisingly) that for many of the network teachers, their definition of student-centered learning and what it means to engage students deeply in algebra changed as they engaged in the work.

Early definitions of engagement: Students are either engaged or they are not

In the early work, teachers thought about successfully engaging students in very stark terms: either they were engaged in the "it" (whatever instructional activity the teacher was trying to implement) or they were not. For example, how many students filled out their exit slips? How many students persevered through a hard problem? How many students justified their answer? How many students shared their thinking? One teacher reflected,

> *Because I was so focused on defining student engagement as a go / no go, engaged or not engaged, doing work as opposed to not doing work, the instruments that I designed to make those measures were not as precise, focused, or capable of providing the information I needed when it was over.*

Evolving definition of engagement: Tied to DEAs and specific change ideas

As teachers in the network engaged in this work over time, interview data reflects that for some teachers, their understanding of engagement changed from this more generic conceptualization of engagement (are students doing the "it"?) to a more nuanced and content-specific conceptualization (are students doing "it" with quality within mathematics frames?) Some teachers clearly articulated how their definition of engagement changed over time as a result of the work they were doing in the network.

> *I think [my definition of engagement was] refined through working in this network. I think about engagement more—I don't want to say deeper, but that's kind of what it is. With more purpose. With more meaning. … I always thought engagement tends to be something that is just straight visual. Students are working, students are quiet. So it's this volume thing and students are doing something. That's engagement. And through this work in this network it's pushed me to think of how to make it meaningful. And to make it meaningful by asking, 'What task am I doing?' And so, it's helped me a lot in my practice, tremendously, because that's not the type of push and discussions I'm having on a regular [basis] in the current school environment I'm in.*

Other teachers shared how the way they thought about engagement changed with the change idea they were using. For some, the definition of engagement (and what it means to get students engaged) is very much tied to the quality measures that teachers grappled with throughout the year. As the teachers worked on defining quality, the content specificity of their definition of student engagement became much more nuanced. For example, teachers went from excitement over a written justification to puzzling over what it meant to give a quality mathematical justification for that specific problem.

I think when we started, we were so happy kids were writing, we gave them a lot of credit for things that really—they were just saying nothing. Now, we're more purposeful, and this is where the network has come in handy. Before we read them, we say, 'What is a quality response to this going look like?' We try to think that out ahead of time.

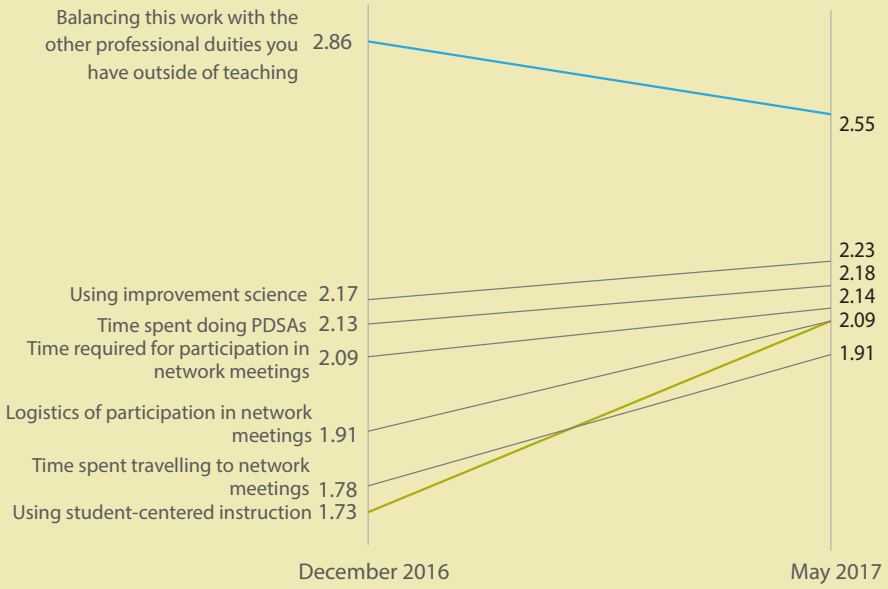
For some teachers, there was a press for "authentic engagement": How do I know my students are intellectually engaged in the work and not just compliant to please me? A few teachers are grappling with the balance between these different definitions of engagement (are the students doing "it"? Are the students engaging with quality?) and what that means for student learning.

As teachers define quality of engagement, implementing student-centered learning became more of a challenge

Although the network provided teachers with a routine for continuous improvement, professional collaboration, and exposure to new ideas, tools, and resources for student-centered learning and increased engagement, the challenge of using student-centered learning increased as the year progressed. In December we asked teachers, "What have been the biggest challenges related to your work with BMTN so far?" They listed a wide variety of challenges, none of which was using student-centered instruction. However, the end-of-year survey reflects a slight, and somewhat surprising, shift. This shift is reflected in Figure 4.5, which shows the change in means (on four-point scale). In December, ten teachers found it not at all challenging to use student-centered instruction, while in June only seven teachers noted this. Additionally, nine teachers marked it as moderately challenging (the highest level of challenge selected by any teacher) in June as compared with only four in December.

Figure 5.5: Shift In Challenges

There was a shift from **process challenges** in December to **learning challenges** in May



Later in the year, as teachers were confronted with decisions about measurement and quality, this work problematized aspects of student-centered learning that they had not previously considered. We hypothesize that as BMTN teachers thought more deeply about what they were doing, why, and to what effect, their perception of the challenge of using student-centered instruction shifted.

Network design supports overcoming challenges

Changing teaching practice is hard. The BMTN Hub created an environment for teachers to try new ways to engage in student-centered learning in a variety of ways. To begin, the BMTN recruited teachers who were already engaged in student-centered learning as well as teachers who were interested in engaging more in student-centered learning. Having a range of teacher experience and expertise in the network enabled lively collaboration.

A safe environment to take risks and fail

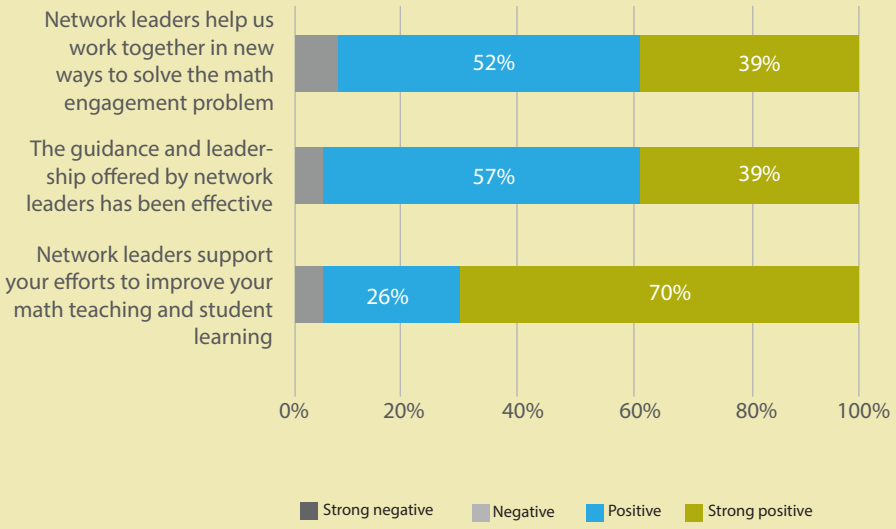
The Hub created a safe environment for teachers to take risks and fail. All of the teachers agreed or strongly agreed with this statement on the June survey: "It feels safe to try new things in this network, even if they may not work." The PDSA process also builds in failure as part of the work.

Leadership support is strong

BMTN teachers felt supported by the Hub leadership. Survey responses from network participants reflect a perception of strong support from the BMTN Hub for their work, as reflected in Figure 4.6.

Figure 5.6: Teacher Perception of Hub Support

Teachers perceive **strong support** from the BMTN hub for their work

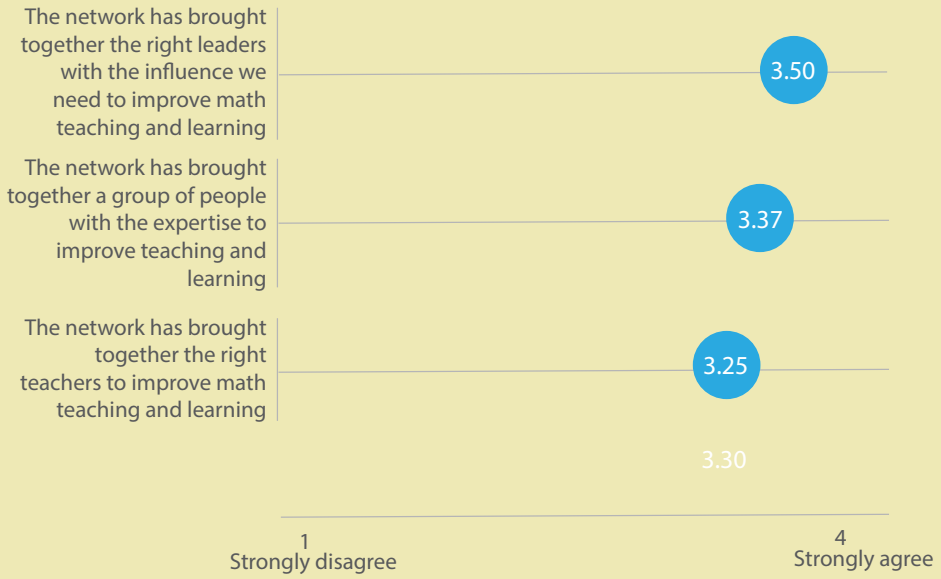


Access to expertise

The Hub leaders have high math content expertise. They are all former high school and/or college math teachers. The access teachers have to each other, and to the Hub, allowed them deep mathematics and instructional support as they engaged in their continuous improvement work. See Figure 4.7.

Figure 5.7: Access to Expertise

Teachers feel that the network has included the right people to influence change in math teaching and learning



Conclusion

Teachers reported significant shifts in their understanding of engagement, the instructional practices around student-centered learning in mathematics, and their professional practices associated with continuous improvement. Early in the year, challenges with the process were more prominent, but by the end of the year, teachers were more likely to observe and engage with the challenge of student-centered instruction. Teachers believed that the Hub leaders offered the expertise and supports they needed take the lead in changing their practice to better meet the needs of their students.

Chapter 6:

Influence on Students

Engaging diverse student populations: BMTN intentionally designed to target high-need students

Problem statement

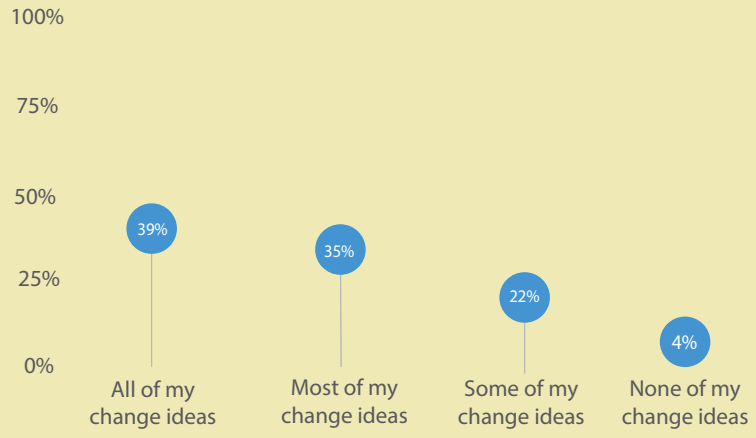
The following problem statement drives the work of the Better Math Teaching Network: Too many high school students are not meaningfully engaged in learning algebra, limiting their opportunities to succeed in school and career. As a Hub leader shared in a network meeting early in Year 1, "The [Nellie Mae Education] Foundation was interested in disadvantaged, at-risk youth. We landed on Algebra I or the equivalent, in part because if you are a 9/10/11th-grader still in Algebra I, you are more likely to be at risk." The network's overarching design targets a diverse population of rural, urban, and suburban classrooms from across Maine, Vermont, New Hampshire, Massachusetts, and Connecticut. In addition to these, Year 2 targets urban schools in Massachusetts and Rhode Island, as those were underrepresented New England populations in Year 1.

Improvement science frames student engagement

In an effort to solve this problem of practice, BMTN teachers focus on this aim: to engage more students deeply in algebra by providing them opportunities to justify, connect, and solve with quality. By engaging in continuous improvement, using tools and routines of improvement science, teachers are supported to target all students in their work. As shown in Figure 5.1, teachers believed their change ideas include opportunities to intentionally support all of their students.

Figure 6.1: Opportunities to Intentionally Support All Students

Teachers believe their change ideas include opportunities to intentionally support all of the students



Teachers identified change ideas to engage all students with depth. They targeted specific places in their practice where they could provide more opportunities for students to engage with depth (using process maps and student survey data). And many of them moved their practice to be more student centered, identifying change ideas that engaged students differently, and engaged different students. The PDSA cycle framed their work, created deadlines and accountability, pressed for change ideas that targeted all students, and—in the study phase—pushed them specifically to understand the following: How well did I do the change idea? Did the students do it? To what extent did the students do it with quality?

Teachers select one "test" class

Most BMTN teachers focused their improvement science cycles on one of their classes, although a few collected data from all of their algebra sections and many implemented the change ideas across all of their algebra sections (and sometimes across other math classes they taught). In a few cases, BMTN teachers did not have an Algebra I section in SY 2016–17; those teachers focused their work on Algebra II and statistics classes. Teachers had a variety of reasons for choosing their "test" class. Some teachers only taught one section of Algebra I. In other cases, teachers chose the class where they had the most parent permission slips returned (enabling them to video tape their classroom to examine their own practice). In several cases, teachers did not do the improvement science work in their sections where students typically struggle, for a variety of reasons. For example, class size was a factor that influenced this teacher's decision:

> *For students—like my full inclusion class—where they have different—they need accommodations, modified curriculum—I'm not using a lot of the [change] ideas that I'm doing [in my other Algebra sections]. Some of that I think is just the context. They're a small group of six students. …So, since it's a small group I can interact with them differently.*

In at least two cases, BMTN teachers selected the section with students who typically struggle in math. It is interesting to see the variation in approaches teachers took to identifying a class to initially target for improvement work. While as a field we do not know what an optimal approach might be, continuing to explore how class characteristics interact with teachers' capacity to build their knowledge and facility to use improvement science methods is worth ongoing attention.

A different high school math class

What is the influence of this continuous improvement work on students? We offer an account of teacher conceptualizations and perceptions of the impact this work is having on their students[7]. According to BMTN teachers, math class looked and felt different for students in BMTN classrooms in three distinct ways: students were engaged differently, different students were engaged, and the classroom learning culture shifted.

[7] We did not collect empirical evidence to measure change in student engagement or student learning; rather, we explored teacher PDSA documentation and had conversations with teachers about their classrooms and their students. The network is measuring changes in student engagement as they examine whether the network is making progress toward its aim.

Students were engaged differently

In a traditional high school math class, the teacher often lectures, gives lecture notes (in some cases, telling students exactly what to write down), and solves sample problems on the board. In this type of classroom, students often sit back and let the teacher do the "work." In BMTN classrooms, most teachers shared that their students were often doing the work that teachers in traditional classrooms typically do: talking about math, teaching each other, making generalizations, choosing their own solution path, looking critically at their work and the work of their peers, finding different rules and principles, looking for and thinking about different strategies to solve a problem.

BMTN teachers reported that in their classrooms, when they were executing their change ideas, students were active, accountable to the learning, and expected to participate. This happened in a variety of ways, including students enacting their unique role in a collaborative task, filling out an exit ticket, or identifying which strategy to use to solve a problem. Students in BMTN classrooms were:

- Working in groups more often
- Learning from each other
- Making discoveries
- Driving their own thinking
- Sharing their thinking and problem-solving with the whole class
- Critiquing the work of others
- Working individually and then sharing their thinking with a partner or small group
- Solving problems with a learning partner and getting help from each other (not the teacher first)
- Writing reflections, justifications, and critiques

This is a very different way for students to engage in math class, and to "do math." In some cases, teachers reported growing pains. If students have not been exposed to student-centered instruction, they may have very deeply held beliefs about what "counts as learning" and what are appropriate roles for teachers and students in a learning encounter that do not align with a student-centered model.

> *There are kids who get really angry—[they say], 'You're supposed to tell me how I'm supposed to do this.' They want me to just tell them … how to do everything, and I think sometimes it's hard for them to then … tell you instead of you always telling them.*

More students engaged in math class

In BMTN classrooms, teachers perceived that students were engaging in mathematics in different ways, as described in the last section. Additionally, the majority of the teachers shared (in interviews at the end of the year) that the change ideas they tested engaged more students. One of the teachers explained how she knew more of her students were engaged as a result of her change idea:

One of my study questions was, 'Will this strategy get more students to engage in class discussion? Currently, about 5 of 14 students participate.' Then, the results were, '9 of 14 students have participated in class discussion, either by sharing strategies, asking questions, or sharing stuck points.' So, we definitely increased the number.

Another teacher noted:

I definitely think I'm engaging more students and different kinds of students. I think before I was really focused on student-centered learning, I was engaging students mostly in a compliant way. [Students would] work hard and try problems, but on a very surface level, not because they're actually interested in it or having conversations about the work.

Different students engaged in math class

In December, some teachers shared that as a result of the implementation of their change ideas, they saw a change in some students who typically struggle in math. By June, half of the BMTN teachers shared anecdotal evidence that as a result of their change ideas, different students were engaging. Many teachers shared at least one story of a student in their classroom who typically was not engaged in math class but was engaged when the teacher tried a change idea. In these stories, we see the following patterns of shifts in which students were engaged in the mathematics.

Some teachers focused on the change in engagement they saw with students who did not typically speak publicly in class.

She had written that she really likes it because there was structure for sharing out, and it gave her a voice.

If I called on her she would answer, but [she] wasn't really willing [to share in class], and she was pretty shy. But she was a great learning partner. She really was a good listener and a good helper of other students in the class.

Some teachers emphasized the effect they saw on students who had a history of challenges learning and/or engaging in mathematics classes.

Those [struggling students] were the students who I felt were more engaged because they said to me, 'I can't believe how well I'm doing in your class. I never did this well in math before. I don't know why it's working for me.'

I had one student in my Algebra I class who really just had no interest in learning Algebra I. He almost failed. Very smart kid but just didn't do any work. But he would be the most engaged in these [change idea] activities; he liked working with other people. He liked the discussing and trying things out and it was always interesting to watch him interact with the other students in his class because it really—I think it helped him the most. He would actually learn the material more when we do these types of activities than if it was just taking some notes and practicing with it. I would see better results on his papers.

With the student with the IEP, I noticed it didn't just change her and the conversation, it also changed the way that she tried during the individual time because what she would normally do is not try because she didn't want to have wrong answers on her paper. So [before this]

when we went over the answers she just didn't have an answer instead of having a wrong answer because she thought a wrong answer would be worse than not doing it at all. So [now during] the individual time she worked harder because she knew that she might be person A for that question who had to give an answer or person C, who had to say whether or not you agree and give a reason.

And another teacher noted the increasing engagement of the "middle of the road math group."

This work really pulled some leadership qualities out of some of my students that maybe [were in] the middle of the road math group. They certainly have strengths in other areas like getting conversation going. And I think because they were strong on that side of things, others saw them as really good mathematicians. And when I don't have those kind of conversations, they didn't really have that opportunity for others to see them that way. When you're only going for a quick right answer, those top students are always the top and everybody just kind of goes, 'Yep, that's interesting. They got it again.' But when you're looking for more depth and conversation about what kind of habits do we see here and what do we think about this and why do we think this is wrong? Or once in a while, some of my problems would be like: here's something. Is it always right? Is it just sometimes right? Those kinds of conversations make kids have to slow down, and it gave a chance for that middle to shine a little bit more.

This teacher's observation of her middle students reflects that in this case, the definition of what it meant to be good in math was broadened. One possible advantage of work to make teaching more student centered is for teachers to see that all students can be successful mathematics learners.

Teachers are continuing to grapple with the engagement challenge

From time to time, in network meetings, coaching meetings, and interviews, teachers shared about and/or discussed their students who they perceived to have the most trouble learning mathematics. They asked: "How can we help the unmotivated kids?" and "How do I reach those kids who are not doing it?" They brainstormed ideas, shared what had worked for them in the past, and asked probing questions. Some teachers reflected on these students in interviews:

I think it depends on the individual, obviously, how much you can push them to speak. There are a couple of boys in that class I can't get to talk either. … I can push and push, but there's only so far I can push on any given day. … It's like, 'Well, did I not phrase the question right?'

[The change ideas] definitely didn't help with the kids that were completely disengaged. But that had more to do with their life outside of school than their life inside of school. The kids that I have that did not engage this year were students who had emotional difficulties and can't engage in anything until everything is okay in the rest of [their] world.

High school algebra: From a culture of memorization to a culture of learning

One BMTN teacher articulated the engagement problem in algebra in this way:

> *Engagement with algebra, traditionally, at the high school level, has probably been the most difficult thing because of the way it has been taught as a set of rules that you have to memorize and follow, or a set of procedures that you just have to watch the teacher do and then practice a hundred times. Which, you know, is pretty boring and not very engaging at all…*

The network is pressing teachers to shift away from that traditional model. At the end of Year 1, BMTN teachers reflected on ways in which they have changed the culture in their classrooms, from one of memorization and listening to a culture of learning. One teacher shared,

> *I think the math mindset work that I did at the beginning of the year was a really good way to start the year, lay the groundwork about everybody talks, everybody makes mistakes, math learning is not nice and neat.*

Another teacher reflected,

> *Students must take responsibility for the learning. They must be the ones who make it happen … [during] private reasoning time—you have to take responsibility to actually do that. Take responsibility to share your ideas, report out your ideas, take the responsibility of your own learning but helping other people as well.*

As a consequence, teachers noticed the ways students thought about themselves as learners, and how they engaged with each other also changed. Some teachers noticed shifts in thinking (students became more comfortable making mistakes) and shifts in how students engaged with each other. For example, one teacher shared,

> *You always have kids who are like, 'No. You're wrong,' and they can be almost mean about it. But these kids wanted to let [their peers] know that they made an error in their thinking, not that that's necessarily a bad thing. That it's also a learning tool. I didn't have that before.*

The intersection of learning and engagement: Deeper learning, different learning

BMTN's theory is that increasing engagement will (ultimately) increase student learning. While measuring student mathematics learning is not a focus of the network, a few teachers did identify evidence of student learning. For example,

> *Comparing this group to last year's group—which is a very similar [group] to them—and I'm looking at some skills and concepts that we have covered and tests that they have taken, I'm like wow—collectively they did a better job than this group did last year.*

> *With the reflection questions that I did this year I was able to see marked improvement between the first attempt that they made at the reflection question, and then the second attempt. So, I was able to see, by student, a progression in their writing in math, in their understanding, and their attempts to connect procedures to concepts.*

Some teachers are grappling with the connection between engagement and learning, and what this means for their own practice:

> *Oftentimes we think of engagement as the starting piece of the work. Are students willing to work on the problem? Will they struggle with it? But my focus here was what they're learning at the end. So, it's a little harder for me to say if it improved their engagement overall. I was really trying to improve their learning: can I get the idea to stick? But they'd have to already be engaged almost to get there. So, I guess I have to think more about that.*

For another teacher, early change ideas were measured in engagement: Did the students talk more often? Did they talk in this structured way? Did that shift not only whose voice was heard but how they interacted with each other as they had these classroom discussions? In those cases, she did not build a rubric to measure learning; her measures focused on elements of engagement. In later change ideas, this teacher designed a rubric that measured learning to test her change idea. This brings forward the idea that learning and engagement might both be measured in the PDSA cycles, but they are tied closely to the specific change idea.

Student-centered teaching contributing to student success beyond Algebra I

Teachers described ways in which their students were changing as a result of the implementation of these change ideas in a variety of ways that extended beyond increased engagement or improved math skills.

Increased confidence

Some teachers talked about the increased confidence students had in themselves:

> *I think [the change idea] provided students more opportunities to talk to each other about the math that they're learning and … instead of having a conversation between the teacher and the student, they're relying on other students as well, building more confidence about yes, … I know that's right. I don't need the teacher to come over here and tell me it's right.*

Improved academic behaviors

Teachers also noted improved academic behaviors. Several teachers noted an increase in perseverance. Students would stay with a problem longer; some would try and struggle for longer before giving up or asking for help. A few teachers described a willingness of students to try hard problems, even when a solution path was not clear. Since in many BMTN classrooms every student was expected to contribute, more students did the work/task/activity instead of allowing the

teacher or their peers to do the work for them. Teachers noted increased willingness to take risks, make mistakes, and work with others. Some teachers noted that students now had new and better collaboration skills.

Potential for math success in the future

Several teachers wondered if the work that they were doing this year would have an influence on students in future mathematics endeavors.

> *I think it's hard [to measure impact] because I think that a lot of what we do probably has a delayed effect. It might be that my students next year when they have another teacher, it would be interesting to see when they're taking a more advanced class than they were with me, in that next level up, how are they doing? Did those soft skills that they practiced and learned in my class help them for their future math class?*
>
> *I'm hoping maybe some of our problem-solving here and looking at patterns might help with SATs.*

Some teachers noted math skills that would carry into future math courses: an ability to make better connections, to apply different problem-solving strategies, to talk about their reasoning, to critique the mathematical reasoning or problem-solving of others, to write a math justification or back up a claim with evidence.

Conclusion

The majority of the teachers in the Better Math Teaching Network think that the work is positively affecting their students. Despite the added complexity and cognitive engagement this kind of teaching requires of students, teachers believed that since they began participating in BMTN, more and different kinds of students were engaging more in math and in different ways. They reflected on how this work has a variety of benefits to students, beyond the aim of increased engagement and beyond the need to increase student test scores in the short term. BMTN teachers believed that their students were building life skills as well as deeper mathematical understanding.

Chapter 7:

Looking Toward the Future: Spread and Scale of Network Impact

Participating teachers reported that the Better Math Teaching Network is providing significant learning opportunities and, through their eyes, affecting their teaching practice and their Algebra I students' engagement in mathematics. Networked improvement communities, like BMTN, aim to become robust learning communities, through which educators learn how to improve practices and, ultimately, systems that address persistent problems of practice. To realize the NIC vision, however, networks must do more than provide opportunities for individual teacher professional development. The aspiration is that networks will harness the social power of collaboration to accelerate learning to solve the problem in the local contexts where participating members work, and possibly in other contexts beyond the network's boundaries. A critical question for BMTN, then, is the extent to which and how the network is developing and implementing a strategy that enables the network to affect educational practice and outcomes, within and beyond the classrooms of participating teachers.

We examined the issue of spread and scale by seeking to identify the network's explicit and implicit approaches to expanding its impact. We found that network leaders and participating teachers emphasized two types of learning that might be spread within and beyond the network: concrete instructional changes that promoted student-centered learning in classrooms and the capacity to utilize improvement science methods to solve problems of practice. Additionally, network leaders and participating teachers spoke about spreading instructional changes and improvement science methods in multiple levels with different audiences: (1) among teachers within the network; (2) with teaching colleagues and instructional leaders in participating teachers' schools; and (3) with the field more broadly, enabling their learning to reach educators in other schools or districts. In this chapter, we explore how teachers and network leaders talked about how to spread their learning as they sought to scale their network's impact.

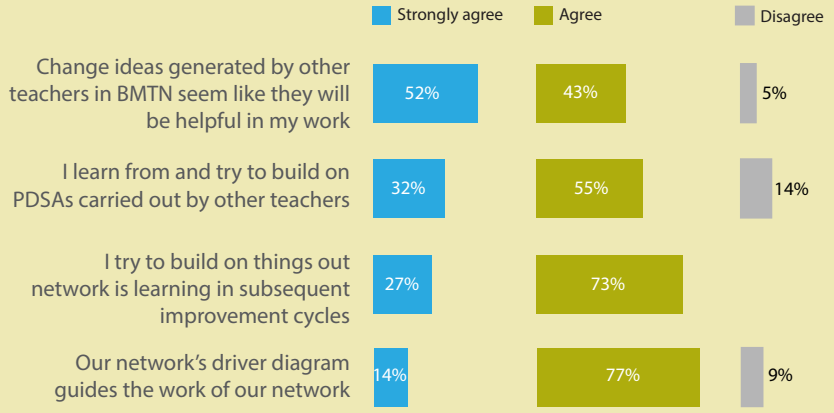
Designing opportunities to spread what teachers are learning about student-centered instruction in Algebra I to other teachers within the network

In network meetings, Hub leaders emphasized that a key goal of the network is to build a bank of resources for practical use, emphasizing that teachers should refine change ideas through iterative testing until they produced engagement from most, if not all, of their students and the change became a regular part of their practice. This culminated in a charge, at the network meeting in March 2017, for teachers to have something that they learned that they could put down on paper and share at the May meeting. Teachers were urged to think about what change ideas they thought were most efficacious and summarize their testing and what they learned. Network leaders provided a template to scaffold teachers' reflections that was designed to capture the learning specifically enough so that it could enable another teacher to test the change in his/her classroom. The template included prompts for teachers to summarize the problem they were trying to solve, what they learned, and what they would recommend other teachers take away.

There is some evidence that teachers took up the ideas shared by their network colleagues. In surveys, teachers reported behaviors consistent with the social learning aspects of the network, such as building on what the network is learning in subsequent improvement cycles and being driven by the network's working theory of improvement.

Figure 7.1: Social Learning in the Network

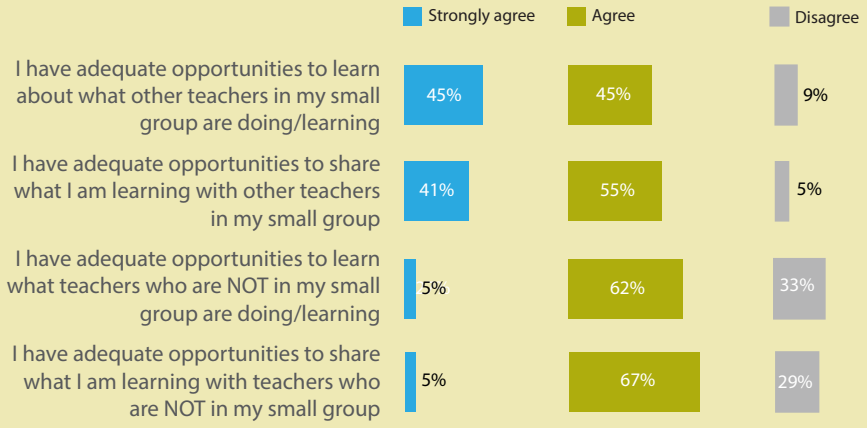
Teachers report **agreement** on items related to the social learning aspects of the network



Additionally, some teachers mentioned intentions to take up what they are learning from colleagues in interviews. That being said, one challenge for BMTN, and networked improvement communities in general, is finding robust and efficient mechanisms for network members to learn from and build on the work of others. A critical participation structure for this learning in BMTN is the small-group PDSA teams, and teachers are generally satisfied with opportunities to learn from these team members. However, teachers would like more opportunities to share with and learn from teachers outside of their small group. See Figure 7.2.

Figure 7.2: Adequate Opportunities to Share

Teachers have **stronger agreement** about opportunities for interaction with teachers within their small groups than teachers not in their small group



This is a challenge the BMTN Hub is actively grappling with and has employed various approaches to solving. For example, Hub leaders have experimented with different protocols for having teachers share what they are learning in face-to-face whole-network meetings. Over time, these protocols have sharpened, leading to greater interaction and deeper exchange of ideas. This will continue to be an important area for continuous improvement of network operations as the networks grows and face-to-face exchange becomes increasingly complex.

The knowledge management role of the Hub

In addition to facilitating teacher-to-teacher exchange of promising change ideas, the Hub of a networked improvement community can play a critical role in knowledge management and crystallization, both of which are key to moving from individual learning to more generalizable knowledge. According to improvement specialist Eva Mejia (2014), "Knowledge management has a natural fit within NICs because they aspire to produce knowledge that can improve practice and expedite the spread and use of that knowledge." Mejia explains that this process is more than generating a repository of tools and lessons learned, but also includes the development of social practices that support adult learning. Additionally, the knowledge management process likely includes ongoing evaluation and reflection on the emerging evidence base to support identification of change ideas that may be prioritized for future testing and spread within the network and beyond.

While teachers are generating change ideas and documenting what they are learning about promoting student-centered learning in Algebra I classes, the BMTN Hub plays an important function in a networked improvement community by facilitating the consolidation and spread of that learning. The BMTN Hub is well positioned to execute this knowledge management role because Hub leaders have deep knowledge of mathematics teaching and learning. In this way, they will have the expertise necessary to develop a framework for evaluating what change ideas identified by teachers have the greatest potential to contribute to the network's aim. Drawing on this expertise, BMTN leaders have laid the groundwork for knowledge management in several ways during its first year.

First, the network developed a system and space for sharing and archiving documentation from inquiry cycles. Teachers upload PDSA cycle documentation and related resources (following a standard template) to shared Google Drive folders. The folders and files are organized so that other teachers can understand the progression of testing and access materials related to the test, such as instructional tasks or ways to measure whether the change is leading to an improvement in student engagement.

Teachers reported general confidence in the network's emerging knowledge management systems. On surveys, nearly all teachers agreed or strongly agreed with positive statements about the Google Drive, such as, "I know when and how to use our shared Google Drive" (96 percent) and "Google Drive supports our collaborative improvement work" (91 percent). Most teachers reported using Google Drive to see what other teachers in their small groups are testing and/or learning (78 percent), however only 40 percent reported viewing what teachers outside of their small group are doing through Google Drive.

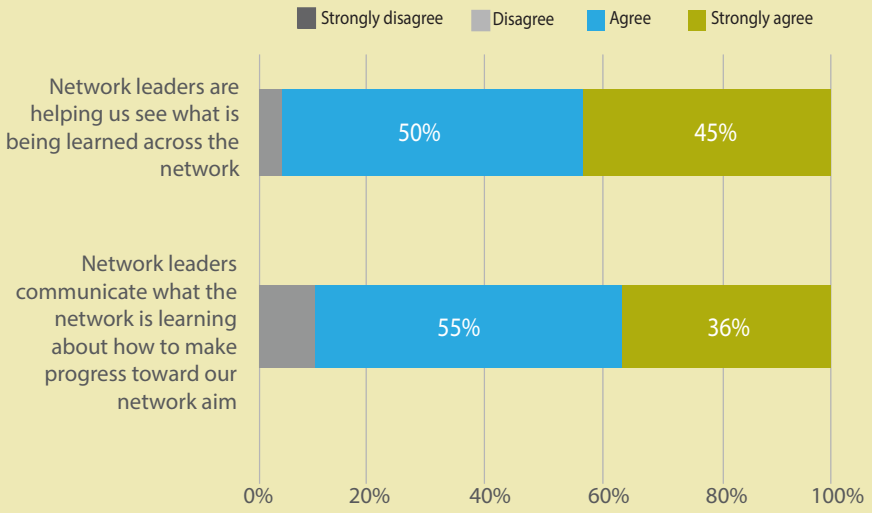
The Hub has also played an active role in facilitating the effective documentation of teachers' change idea summaries. They built a template to frame critical elements for each teacher to share, and commented and edited documents to ensure the clarity and specificity necessary to make the summaries useful to other educators. Teachers and Hub leaders went through multiple iterations of

revision for each change idea summary. This culminated in the production of a change idea summary book that was distributed to all teachers. As the network puts their change ideas out to the broader world, the Hub can use their deep content knowledge to ensure the ideas shared are high quality.

Overall, BMTN teachers reported that network leaders are helping them to see what the network is learning. The majority of BMTN teachers agreed that "network leaders communicate what the network is learning about how to make progress toward our network aim," and "network leaders are helping us see what is being learned across the network." See Figure 7.3.

Figure 7.3: Network Leader Communication About Progress

BMTN teachers **agree** network leaders are communicating and sharing network learning with the group



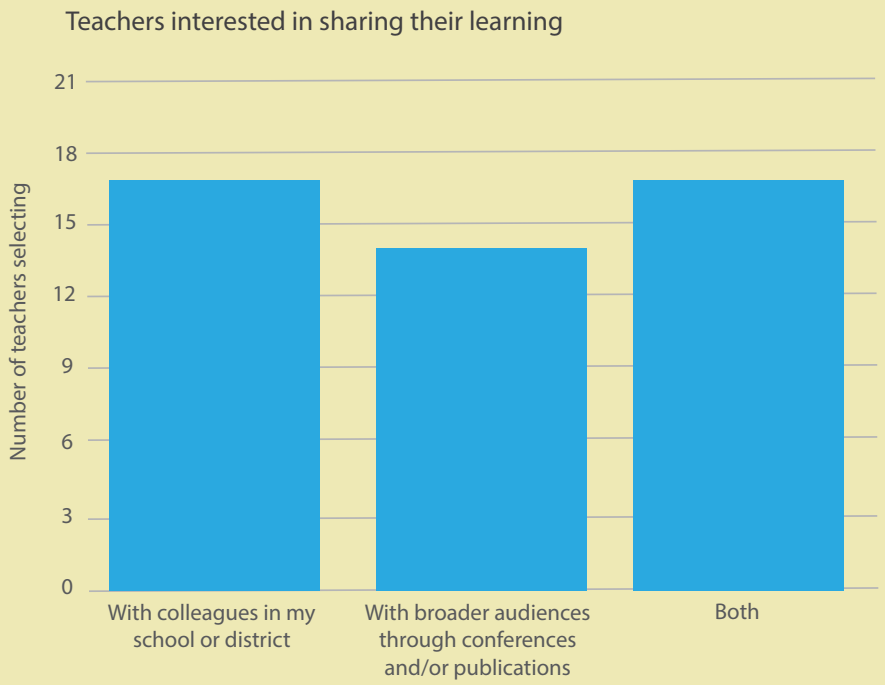
Emerging approaches for spreading learning about student-centered instruction within participating teachers' schools and beyond

The next level of spread and scaling for BMTN is sharing what the network is learning about student-centered teaching and learning with educators who are not members of the network. In general, BMTN teachers are enthusiastic about sharing what they are learning with colleagues within their schools and beyond. Through an open-ended survey item, 21 teachers reported interest in sharing what they are learning with people outside the network, with most (74 percent) identifying ways to share with local colleagues in their school or district, but many (60 percent) also reporting interest in sharing with broader audiences through conferences, publications, or social media. Responses included:

This year I shared some of my findings with my colleagues individually and briefly in a group setting. I recently became the math coach at my school and will use not only my findings, but the findings of the network in my work as coach next year. Additionally, I would be willing to present at any regional or national mathematics conference.

I've already written blog posts about the work and have several more in the pipeline. I've tweeted #BMTN when we are together … I will be presenting a session about my work at the ATMNE [Association of Teachers of Mathematics in New England] conference in the fall and have submitted speaker proposals for the NCTM [National Council of Teachers of Mathematics] and NCSM [National Council of Supervisors of Mathematics] annual meetings. Kirk & Toni [Hub leaders] have talked with me about writing an article for Mathematics Teacher.

Figure 7.4: Teacher Interest in Sharing Learning[8]



In interviews, many teachers reported sharing math ideas and resources with their school colleagues.

I share some things and some of the articles. I really like the TRU Math rubric. I brought that back and shared it with my math department.

My department chair actually just asked me the other day if I would be willing to talk with our math curriculum coach about the work that we are doing, so there's definitely some buzz and some interest in this idea of trying to create less traditional and more student-centered math thinking. The idea of what we are doing is definitely spreading, and it is in a positive way.

[8] Two out of 23 teachers did not respond to this open-ended survey item. It is not clear if their non-response should be interpreted as unwillingness to share or they simply did not complete the item.

I share my work with the network with my school colleagues both explicitly and not explicitly. I'll definitely say, 'At my math network meeting this came up and this came up.' And so we'll sometimes talk about some of those ideas. Other times I might have realized that we had another great resource or we taught facts in a certain way or I'm trying my change idea with something in particular. I'm trying to incorporate that into the work that I'm bringing to my math team without explicitly telling them that it came from my math network.

I just came back telling [a colleague] what my new change idea was and how I wanted to implement it. We share a lot of the same kids still even though we're not team teaching. It's just the classes we have. So then he'll say, 'How can I support your work?' or 'Hey, can I do that piece of it also?' or things like that.

Building leadership capacity to support the spread of emerging knowledge about student-centered learning

The network is also beginning to address the structural and systemic conditions that enable (or constrain) teachers' capacity to become more student centered by engaging a group of district-, state-, or school-level instructional leaders in identifying ways to spread and scale the network's impact. In whole-network meetings throughout the year, Hub leaders talked about how change ideas and related learning could be shared through instructional leaders and mathematics coaches. Hub leaders recruited a small group of educational leaders to meet regularly and discuss spread and scale issues. Additionally, some leaders attended the final whole-network meeting to learn about what teachers were learning through their inquiry cycles.

When we talked to some of these leaders in end-of-year interviews, they shared great excitement about the work and reflected on how the BMTN's work aligned with goals they were working to achieve in their different leadership roles. They also had ideas of their own about how they might spread the work in their own contexts. One district leader shared:

Our district just recently set a district priority around engaging all students in standards-aligned, cognitively demanding tasks. We've been creating and providing a lot of professional development for teachers around that priority. At the same time, we're also trying to bring into our high schools new curriculum materials that have lots of rich tasks and are designed with the kind of pedagogy that would be pretty consistent with what we would call a student-centered classroom. … We know classroom-based support is going to be really critical if our efforts are going to succeed. This project just seems like a lovely way to build some of the support at the school level.

Another district leader saw the work as useful for non-network teachers in the following way:

I think if they share the strategies and how they tweak things to work for their settings, it offers opportunities for teachers who may not be quite ready yet to come up with a plan on their own to try something someone else had already done, because we're very pressed for time. Teachers don't have the opportunities for—as awful as it may sound—that thoughtful reflection to make adjustments. You're going from class to class, day to day, with no down time to think about how did that class just go? And what might I want to change and apply? But the deep, full thought may not occur until much later on.

Similarly, a state leader pointed to changes in practice due to involvement in BMTN.

> *The impact of being involved in this work has been significant in my role here at the Department of Education when I think about building capacity across the state and having impact and effect in classrooms statewide as opposed to in a particular school or a particular region. Using that model of change science and the driver diagram is how I now approach the professional development that I planned and deliver across the state. … I've shared my approach to planning, and implementing, with the other specialists here at the Department of Education, and several of them are jumping on board with this practice of looking at, what is my overall goal? I'm going to pick one thing and try to see how that impacts change, and next year I'll try something else, and tweak along the way. So I'm getting to see some trickledown effects and changes here as well with my colleagues.*

Building capacity for the use of improvement science to tackle problems of practice

In addition to the spread of change ideas and what teachers are learning about promoting student-centered learning, another way BMTN, and networked improvement communities more generally, might scale their impacts is through the spread of improvement science methods. Teachers in BMTN are enthusiastic about how improvement science contributes to educational improvement.

Some teachers have shared methods and tools with colleagues in their school and beyond. In at least two schools, BMTN teachers have shared the process map tool with colleagues, who have taken it up as a way to identify areas of their instruction on which they want to focus. Other teachers have talked about the PDSA cycle with co-teachers and other math department members.

> *When I come back from the network I say [to my co-teacher], well, this is what I'm working on. You don't have to collect the data [laughter], but you're welcome to do it too. We're basically collaborating on this course that we're teaching together and work together on planning it. The data part of it is the part that she's not collecting, but we are doing similar things in that class.*
>
> *It's not really just the mathematics, but rather I share what we've been doing within the network, and we talk about how things are improving and what we've changed.*
>
> *I tend to talk to [my math department] more about the process and basically what I'm hearing about other schools. I also talk about some of the data work I'm doing and some of the ideas I'm coming up with and trying to implement.*

In some cases, teachers wondered in interviews about whether their local context is ready to engage in improvement science.

> *There is other work that we have to do during our math department meeting, so there isn't all this space to have this conversation. Which is too bad, because I think it would be useful. We're not quite there yet. We're still a brand-new school in a lot of ways.*

As far as spreading this in my K–12 work, we've talked about this a little bit, but I'm really working with them more on basic math. [Things like] if you don't know what you want for a result, maybe think about that before you teach the lesson. … [In terms of teaching them about improvement science,] I'm not there yet with them.

The willingness of BMTN teachers to share their process with school colleagues, and the interest school colleagues are showing, reflects possibilities for deeper spread of improvement science. To achieve that, a possible next step will be to articulate a clear theory of how the spread of a complex process will take place outside of the network. Who in the school will serve as the champion? What resources do the BMTN teachers need to bring improvement science to others? For example, how might the teachers obtain broad buy-in? How can the Hub or the network provide technical information? The Hub has provided intensive coaching for participating teachers; how might broader scaling work without these resources?

Teacher confidence in the scaling strategies

A number of teachers commented on the network's approach to scaling in interviews, saying they could envision it leading to broader impacts over time.

I could imagine being a part of this for a couple of years and maybe just trying other people's change ideas and seeing how it works and documenting that, that we also are able to share these ideas in a way that helps other teachers to do the same thing so that number [of teachers currently touched by the network] is very narrow for what we are doing in it, but I think what its ripple effect is or has the potential to be is very powerful.

I think it's a really interesting project because teachers are identifying the place where they want to improve in their practice, specifically around engagement. Then they're working on that for quite some time. They're working with their colleagues, and so I think it has a tremendous impact to really change student learning, and to make learning more student centered. It also seems to be embedded in practice. A lot of times what I'll hear other teachers say is 'I can try something like that once in a while, but I can't do it every day.' But these practices are meant to become regular. So, I think that has the potential to be really powerful.

I think [the BMTN] could be a pretty big deal—if we get together and have a general organizational structure for people to access some of the PDSAs we've been through and talk about it at conferences, there are going to be a lot of people interested in the things we're doing and improvement science in general. But especially for math instruction, I think it's a really good thing. I'm currently going for my administrator's endorsement. I love teaching … but if I ever get into an administrative position or into the area of curriculum, I'll definitely be having most of the teachers doing improvement science.

However, some teachers wondered about whether this strategy for scale would be sufficient to help other teachers make the fundamental shifts in teaching practice required for Algebra I classrooms to be student centered. For example, one BMTN teacher said:

> *I'm also not sure about this step to scale—is writing up a change idea and passing it on really enough? I get the acceptability of let's package some ideas and get people started, but I feel like the change is so fundamental that small things may end up just being surface. Which may be better than nothing, but I'm not sure people really get the fundamental vision of what is different in the classroom compared to the way we currently teach.*

Some teachers also noted that it is not always possible for teachers to take up the promising instructional practices identified by other teachers. For example, one teacher noted,

> *I could completely change what we were doing. We had the ability and the freedom to do that. There are people for whom this could make a profound systemic difference, but there are other schools clearly where no one individual at this point, I think, could pull off a truly systemic change. Or even change their classroom so drastically from the way that education is working in the other classes. It just wouldn't really work.*

This sentiment reinforces the need for the network to address more systemic conditions that support student-centered teaching and learning by engaging instructional leaders at the local and state level.

Conclusion

The Better Math Teaching Network is laying the groundwork for spreading and scaling its impact. Network Hub leaders have invested in systems to support the spread of what teachers are learning about student-centered instruction among teachers in the network. Teachers are beginning to share what they are learning about student-centered teaching and improvement science methods with colleagues in their schools and districts. Additionally, teachers are beginning to envision a role they may play in sharing what they are learning with educators beyond their immediate sites of practice, through conference presentations and written publications. Finally, the network has reached out to a small group of instructional leaders who are advising the network on ways to spread and scale what it is learning about student-centered learning and how to promote instructional change at scale.

An important next step is for the network Hub to continue to invest in formal routines that support teachers testing promising change ideas generated by their colleagues in the network. To advance the learning of the network, promising change ideas must be tested under varied conditions. As it engages in knowledge management, the Hub can identify those change ideas that produce desired changes and seem to be adaptable to diverse contexts, and consolidate them in change packages. Change packages describe a set of practice changes that have been found to reliably produce the improved practices and outcomes desired by the network. Fulfilling this knowledge management role will require that the Hub capitalize on its expertise, and that of BMTN teachers, to ensure that quality ideas are advanced and spread forward. This consolidation of learning will require more than generating and spreading documentation and tools, but also the kind of social practices that enable teachers to learn how to change their practice.

Another potentially generative next step is for the network to grapple with how it can support individual NIC members spreading student-centered learning (and possibly improvement science methods) within their own local contexts. For example, how can BMTN teachers be empowered to enact their capacity to consistently share what they are learning with their school-based colleagues in ways that enable their colleagues to try changes in their own classrooms? These changes may

include specific instructional strategies for improving student engagement, but also the improvement science approach to problem-solving. Additionally, how can the network draw in instructional leaders at the school, district, and state level to contribute to building systemic capacity for instructional improvement at scale?

And ultimately, the network will need to come to consensus and clarity on its ultimate strategy for spreading and scaling its impact. This includes gaining clarity about what the network is aiming to spread. For example, is the network learning specific ways to promote student-centered learning, improvement science methods for learning to change processes and systems, or both? The network will also need to identify the high-priority, systemic levels that must be engaged to meet its aims. For example, will the BMTN strategy be to spread to more teachers, more schools or districts, and/or more educators within the current schools and districts?

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Appendix A: Evaluation Methodology

While some industries, such as healthcare, have used improvement science for decades, the use of improvement science and networked improvement communities is new to education. Because this work is complex, innovative, and relatively new, and because improvement science by nature requires rapid tests of change, adaptation to context, and systems thinking, we utilized a developmental evaluation approach, rather than formative or summative evaluation, to understand and inform the Better Math Teaching Network.

What is The Developmental Evaluation?

The purpose of a developmental evaluation is to support the development of innovation and adaptation in dynamic and complex environments. Indeed, developmental evaluation is best suited for situations of high complexity and when working on early stage social innovations, like the Better Math Teaching Network (Gamble, 2008). The team that is involved in a developmental evaluation acts as an insider-outsider, serving as a partner in the iterative design of the NIC, while also reporting out findings with sufficient frequency to improve learning and support design decisions. Developmental evaluation incorporates methodological flexibility, systems thinking, and adaptability. The ability to facilitate rigorous evidence-based perspectives, while tolerating ambiguity and agility, allows a developmental evaluation team to evaluate the complexity of the work of an evolving NIC (Patton, 2006; 2010). Since the NIC concept is too new to be able to clearly identify if a network is "implementing with fidelity" or getting to a "prescribed outcome," drawing on principles of developmental evaluation will inform the work with structured, real time analysis intended to refine the network, push the learning, continue to build capacity within the team, and inform all stakeholders of progress.

Developmental evaluation emerged in response to the need to support real-time learning in complex and emergent situations. Traditional forms of evaluation work well in situations where the progression from problem to solution can be laid out in a relatively clear sequence of steps (Gamble, 2008). However, initiatives with multiple stakeholders, high levels of innovation, fast paced decision-making, and areas of uncertainty require more flexible approaches (Patton, 2008).

Developmental evaluation differs from traditional forms of evaluation in several key ways:

- The primary focus is on adaptive learning rather than accountability to an external authority.
- The purpose is to provide real-time feedback and generate learnings to inform development.
- The evaluator is embedded in the initiative as a member of the team.

- The evaluator role extends well beyond data collection and analysis; the evaluator actively intervenes to shape the course of development, helping to inform decision-making and facilitate learning.
- The evaluation is designed to capture system dynamics and surface innovative strategies and ideas.
- The approach is flexible, with new measures and monitoring mechanisms evolving as understanding of the situation deepens and the initiative's goals emerge (adapted from Westley, Zimmerman & Patton, 2006).

Michael Quinn Patton (2008), who pioneered this form of evaluation, defines it this way:

> Developmental evaluation refers to long-term, partnering relationships between evaluators and those engaged in innovative initiatives and development. Developmental evaluation processes include asking evaluative questions and gathering information to provide feedback and support emergent decision-making and course corrections. The evaluator is part of a team whose members collaborate to conceptualize, design, and test new approaches in a long-term, on-going process of continuous improvement, adaptation, and intentional change. The evaluator's primary function in the team is to elucidate team discussions with evaluative questions, data and logic, and to facilitate data-based assessments and decision-making in the unfolding and developmental processes of innovation.

Developmental evaluation is suited to situations that are:

- Highly emergent and volatile (e.g., the environment is always changing)
- Difficult to plan or predict because the variables are interdependent and non-linear
- Socially complex, requiring collaboration among stakeholders from different organizations, systems, and/or sectors
- Innovative, requiring real-time learning and development (Patton, 2008; Gamble, 2008)

Data Collection

Data collection was cued to the network design and activities. The table below summarizes the data sources and indicates the number of administrations and respondents

Data Sources	Data Collected
1. Network leader self-assessment survey	January: N = 1 leader
2. Network member survey	
• *December*	N = 23 teachers
• *June*	N = 23 teachers
3. Teacher interviews	
• *December*	N = 23 teachers
• *June*	N = 22 teachers
4. Observation and artifacts from network in-person meetings	Field notes and artifacts: October, December, March, May
5. Small group, coaching meetings videos and/or in-person observations	N = 22
6. PDSA documentation	
• *Summer drafts*	N = 43
• *Fall drafts*	N = 26
• *Winter/Spring drafts*	N = 31
7. Change idea summaries	
• *Draft*	N = 26
• *Final*	N = 18
8. Case Studies	
• Classroom observations	N = 7
• Teacher interviews	N = 7
• School leader interviews	N = 2
• Additional PDSA documentation	N = 36

Analytic Approach

Survey data of leaders and members were analyzed in two ways. First, descriptive statistics were used to understand group level responses. Second, some survey items were imported into ORA software package and social network analyses were conducted. These analyses allowed us to explore and visualize the variables shaping formal and informal relationships within the network.

PDSA documentation and **change summaries** were analyzed using a rubric to assess the quality and completion levels of key aspects of the PDSA process.

Field notes and artifacts from network meetings and small-group meetings were analyzed using thematic analysis tethered to our guiding evaluation questions.

Case studies were analyzed using thematic analysis and grounded theory.

Collectively, **the entire data set** was analyzed utilizing grounded theory to discern key aspects of network development that will ultimately inform our understanding of how NICs develop and mature.

Glossary

BMTN: Better Math Teaching Network

The Better Math Teaching Network is a networked improvement community focused on student-centered learning as a potential solution to the problem of high rates of high school math students disengaged in mathematics learning. The network focuses on algebra content.

Change idea

Change idea is a term from improvement science that is defined as "an alteration to a system or process that is to be tested through a PDSA cycle to examine its efficacy in improving some driver in the working theory of improvement" (Bryk et al., 2015). In the context of the BMTN, a change idea is a small change to planning or instruction that a teacher makes in order to examine its efficacy in improving deep student engagement in algebra.

DEA: Deep Engagement in Algebra

The Better Math Teaching Network defines deep engagement in algebra as the extent to which students are:

- Making connections among mathematical procedures, concepts, and application to real-world contexts, where appropriate (connect)
- Making sense of and solving challenging problems that extend beyond rote application of procedures (solve)
- Communicating and justifying their mathematical thinking as well as critiquing the reasoning of others (justify)

These three elements of deep engagement in algebra (connect, solve, and justify) are referred to by the BMTN as DEAs.

Driver diagram

A tool used in improvement science to represent the theory a group has for improvement in a particular problem of practice. The driver diagram guides the improvement work, providing shared language.

Hub

The Hub is the name of the team that leads a networked improvement community. The Hub is responsible for technical support for the NIC as well as for organizing the joint work of the NIC and articulating learning within and beyond the network. In the case of BMTN, the Hub consists of AIR researchers (who were former math teachers) and a school district coach / math teacher.

Improvement science

Improvement science is an applied science that has dramatically improved practice in a number of industries by helping practitioners learn their way into improvement. The approach has a long history in the manufacturing industry and subsequently the healthcare field, and provides a disciplined methodology for learning from practice to improve the systems and processes that shape work within organizations (Berwick, 2008; Deming, 2000; Gawande, 2007; Langley et al., 2009). More recently, education reformers and leaders have looked to improvement science as a way to accelerate large-scale improvement in schools and districts (Lewis, 2015).

NIC: Networked Improvement Community

Networked improvement communities, or NICs for short, bring together practitioners, educational leaders, and researchers in order to solve a pressing problem of practice (Bryk, Gomez, Grunow & LeMahieu, 2015; Hannan, Russell, Park & Takahashi, 2015). In promoting the use of improvement science in networked communities, Tony Bryk and colleagues at the Carnegie Foundation for the Advancement of Teaching have recently promoted the NIC concept as a way for practitioners to learn how to improve education at scale by building an evidence base about both productive practices and knowledge of implementation processes to address persistent problems of practice and policy (Bryk et al., 2013). NICs are professional learning communities distinguished by four essential characteristics: (1) they are focused on a well-specified common aim; (2) they are guided by a deep understanding of the problem, the system that produces it, and a shared working theory of how to improve it; (3) their work is disciplined by the rigor of improvement research; and (4) they are coordinated to accelerate the development, testing and refinement of interventions, their rapid diffusion out into the field, and their effective integration into varied educational contexts (Bryk et al., 2015; Russell, et al., 2017).

PDSA: Plan-Do-Study-Act Cycle

The PDSA cycle is an inquiry routine involving four steps: Plan-Do-Study-Act. The logic of the cycle is that teachers learn how to improve their practice by planning a specific change tied to a working theory of improvement, test the change, study evidence to assess whether the change constituted an improvement, and decide what action to take in light of what was learned. Identifying hypotheses, testing those hypotheses, and comparing results with one's predictions generates new details about how to improve practice. This rapid inquiry generates new learning and allows teachers the opportunity to examine variations in context that support or constrain their practice.

Process map

A tool used in improvement science for "visualizing the steps in a process that can assist an improvement team in identifying gaps, strengths, and opportunities for improvement" (Bryk et al., 2015). In the context of the BMTN, teachers built process maps of a teaching routine in order to identify places in their practice routine to focus their improvement efforts.

Small-group PDSA coaching meetings

To support teacher engagement and promote social learning, the network organized virtual meetings of two to three teachers plus a network leader focused on planning and debriefing inquiry cycles. These monthly meetings provided a forum for teachers to identify aspects of their teaching practice to target for improvement, generate potential change ideas to test, and discuss the results of these inquiry cycles. In these meetings, teachers had the opportunity to dig into specific instructional challenges and improvement strategies with teachers teaching the same content, and a Hub lead with research and practical expertise in math teaching, math learning, and improvement science.

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