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Better Math Teaching Network:

Year 2 Developmental Report

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Better Math Teaching Network:

Year 2 Developmental Report

Partners for Network Improvement
Research, Strategy, & Evaluation

**Learning Research and Development Center
University of Pittsburgh**

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Executive Summary

The Better Math Teaching Network (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, how to improve opportunities to increase student engagement in high school mathematics. During the 2017-18 school year, 41 teachers from all six New England states participated in the second official year of the network's operation. Teachers were selected from a pool of volunteers that 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. Teachers committed to work collaboratively to make their teaching more student-centered using the improvement science approach.

Chapter 1: BMTN Routines and Tools

Routines and tools are often used by leaders in organizations to structure work practices and to catalyze and sustain change. In the Better Math Teaching Network, network leaders designed and refined routines and tools they intended would support both teachers' use of improvement science and their engagement in the network. By intentionally and carefully designing these routines and tools, BMTN network leaders scaffolded teacher learning and supported teachers as they changed their practices. In this chapter we examine three routines and three tools that BMTN network leaders designed and implemented. We consider each routine and tool's designed purpose. We then discuss the benefits and challenges teachers experienced as they engaged in each routine or used each tool, as reflected in our data. Finally, we note possible design implications for the field.

- Routines that were most effective involved regularity, collaboration, and learning.

- Building coherence and connections across routines and tools can streamline messages and learning.

- Balancing in-person and virtual meetings that occur regularly can support momentum, accountability, and engagement.

- The ways that tools are designed can teach users and focus attention on particular constructs or principles.

- Simple tools work well for busy teachers, as does building in time for structured or guided reflection.

- Finding ways to capture and consolidate learning from inquiry cycles is a challenge.

Chapter 2: Influence of Routines on the Collaborative Work of BMTN Teachers

Better Math Teaching Network leaders designed and refined a series of tools and routines to support participant learning and engagement in BMTN. Three of these routines—often referred to as "participation structures" in networked improvement communities—organized the collaborative work of BMTN teachers: network meetings, PDSA meetings, and optional study group meetings. In this chapter we examine the importance of these routines for building and sustaining collaboration, an element critical to both learning and the acceleration of learning in networked improvement communities. Our social network analysis suggests that in general, collaboration among BMTN teachers happens almost exclusively within the formally structured interactions and not informally outside of these designed participation spaces. These findings highlight the importance of the design and use of formal participation structures because these leader-designed structures determine with whom and how intensely teachers collaborate. Given that participation structures largely shape the collaborative work that teachers do, network leaders must intentionally design them to achieve network goals. Participants also noted that the in-person whole network meetings were critical to building and maintaining trust, sparking motivation, and stretching their thinking. While these meetings are resource intensive, teachers see face-to-face time as essential to the work.

Chapter 3: The Challenges of Improvement Science

Learning and integrating improvement science into practice is the biggest challenge teachers face as they engage in the Better Math Teaching Network. In end-of-year interviews, 53% of returning teachers and 78% of teachers new to the network identified an aspect of improvement science as one of the most significant challenges they encountered as they engaged in the work.

Specifically, they spoke about challenges with:

- Identifying good change ideas to test

- Using data and improvement to formally test changes

- Integrating their improvement activities into their workflow (e.g., remembering to do it, fitting it into the flow of classroom instruction)

Once teachers become accustomed to engaging in inquiry cycles, some aspects of improvement science become less challenging for them. However, issues around data collection and measurement persist into teachers' second and third years of participation in BMTN, indicating that this challenge is harder to solve than teachers learning to integrate inquiry cycles into their practice over the course of their first year.

Teachers tend to run into three challenges as they work to design, implement, and use practical measures in the context of inquiry cycles. These three challenges include designing practical measures specific to algebra engagement, collecting and analyzing practical measurement data, and interpreting the findings from their data to understand whether their teaching changes improved student engagement. BMTN teachers note that there may be many potential benefits of using common measures rather than designing their own. They hypothesize that it might streamline the process or build a stronger basis for collaboration with other teachers. In this sense, the diversity of measures used within the network might be contributing to the difficulty teachers had understanding the work of others and building upon it.

Chapter 4: Challenges to Engagement in BMTN

In addition to the challenges related to the integration of improvement science detailed in Chapter 3, BMTN teachers noted other challenges to network participation, and teachers who were new to the network identified different challenges than the teachers who were returning. One of the key issues that teachers had to address is their limited time in relation to the demands of the network. As is often the case with change efforts in education, finding the time to commit to the work is a significant challenge for teachers. BMTN participation requires both carved out time for in-person meetings as well as embedded time for inquiry execution and support structures. Interestingly, despite time being one of the most noted challenges, when an optional study group was offered that required additional time, the majority of BMTN teachers chose to join. This suggests they see great value in network activity.

A number of teachers also noted that the work (both the inquiry and student-centered focus) was often in tension with aspects of their school context. Those with more rigid curricula and pacing found it difficult to inject student-centered activities while still meeting pacing expectations. Others found it challenging to fit in the data collection needed for inquiry given already very full class periods.

Veteran teachers observed differences between network design in the previous year and found less momentum, support, and engagement this year as a result of changes made by network leaders to move to a more sustainable network model. New teachers were more likely to report typical feelings of uncertainty at the outset of engagement while they developed a sense of the work and process as well as challenges finding good math tasks to align with their change ideas.

Overall, face-to-face meetings appear to serve an important function both for momentum and for participant satisfaction with the work. Although other network structures are important, reduction in face-to-face time over the course of the year was evident to teachers and it was missed. As the network scales, there may be a sense of a loss of "intimacy" or personalization, as several returning teachers noted, and attending to the needs of both new and veteran teachers may become more difficult.

Chapter 5: Teacher Perceptions of BMTN Impact on their Teaching

Teachers in the Better Math Teaching Network are working toward the network's common aim: to increase the number of students in algebra who connect, justify, and solve with depth. Network leaders use their knowledge of mathematics and mathematics teaching to press network participants to consider not only if their students are more engaged in student-centered practices around connect, justify, and solve, but to also consider if their students are engaging with quality. In other words, are students doing the work (e.g., a student is justifying her answer) and are they doing the work with quality (e.g., her justification is of quality)?

BMTN teachers agree that their engagement in the network has influenced their teaching in a variety of ways. We briefly note the general influence that BMTN teachers report the network has had on their teaching, and then look more carefully at three ways in which teachers perceive BMTN had an influence on their work:

- Influence on instructional planning
    - Greater attention to task selection and adaptation of existing tasks.
    - More intentionality around task and activity ordering.
    - Greater focus on conceptual understanding rather than procedures only.
    - More intentional use of data for examining student learning.

- Influence on student-centered instruction
    - Teacher reports of amount of instructional time spent using student-centered activities has increased from pre- to post-network involvement.
    - Greater change observed for teachers who came in reporting lower levels of student-centeredness.
    - Teaching practices that changed include those that leverage peers to learn from one another in pairs and small groups and thinking and reasoning about math.
    - Teachers changed their own behaviors, including talking less and refraining from directly answering some questions or showing relationships.

- Integration
    - Testing their change ideas beyond a target class.
    - Sustaining use of change ideas beyond testing cycle.

From these data we can conclude that teachers' engagement in BMTN has influenced their work.

Chapter 6: Teacher Perceptions of BMTN Impact on Student Engagement

In Year 2 of the Better Math Teaching Network, the teacher participants had a combined 936 students in their target classes. These target math classes included a range of courses, but the majority were Algebra I. In this chapter, we report on what we learned about whether and in what ways teachers believe that their participation in BMTN has impacted student engagement in algebra. The chapter first explores how teachers conceptualize engagement and deep engagement in algebra for each of the DEAs: *Connect*, *Justify*, and *Solve*. These analyses show that in some pockets of the work, teachers are developing some shared conceptions of deep engagement while in other areas, especially in Solve, there is more variation.

This chapter also reports data on teacher perceptions of impact on student engagement, including:

- 90% of teachers report moderate or substantial impact on engaging more students. Many specifically report progress in engaging less confident students.

- Nearly all teachers reported moderate or substantial impact on engaging students with quality in the DEA they worked on, with more teachers reporting more intensive impacts for *Connect* and *Justify* than for *Solve*.

- Teachers report that student work now consists of more opportunities to collaborate for math learning, increased expectations around writing and explaining rather than computation or rote learning, and that the onus is more on students to do the thinking and to really understand what they are doing.

- Teachers report that beyond engagement, students' reading and writing in relation to math and math texts/tasks has improved, and students are developing a more conceptual understanding of mathematics principles.

The data presented in this chapter rely on teacher perceptions of impact on student engagement rather than more objective measures of engagement. These findings suggest that BMTN teachers find value in the network for increasing engagement of their students in algebra. This is an important indicator of network sustainability and a potential predictor of increased student learning.

Chapter 7: Scaling the Network

As the Better Math Teaching Network continues to grow, design decisions made by the network leaders evolve and shape participant experiences. In this chapter, we share insights about five key issues in scaling a NIC as they relate to the growth of BMTN:

- *Meeting the needs of teachers at various stages of participation.*
  Our data suggest that new members feel the weight of learning improvement science most significantly in their first year, followed by figuring out how to contribute to and leverage the resources of the network. This suggests that network leaders need to support teachers new to the network on specific, and different, elements than returning members.

- *Maintaining a sense of connectedness within the community.*
  As network membership grows, some returning members experienced a loss of intimacy or connectedness. Network leaders in BMTN worked to mitigate this shift by tweaking the design of whole group meetings and other participation structures.

- *Knowledge management.*
  As the network grows, network leaders have to find ways to consolidate the learning of network members, capturing promising ideas and sharing them in a way that is accessible to all members and that can remain a "living artifact" that reflects the ongoing learning as it emerges over time.

- *Negotiating the tension between quality of the experience and quantity of teachers in the network.*
  As BMTN grew, direct support from network leaders was reduced from previous levels of intensity. In Year 3, network leaders are building new leadership roles for some returning members as a way to mitigate this shift in available resources.

- *Adapting the tools, routines, and roles for scaling.*
  As the network grows, it is adapting the tools, routines, and roles to respond to participant needs in a more generative and sustainable way. Given what we have learned about variations in participant needs based on experience levels, shifts in the sense of connectedness, and the challenge of maintaining quality supports as the network grows, we offer a few considerations for ongoing design and implementation work in five categories: institutionalized mechanisms for transitioning new members, scaling access to expertise and rigor, scaling quality controls, differentiating work and roles, and managing knowledge.

Chapter 8: Spread in Year 2

One promising feature of an instructionally-focused NIC is that the field of education can potentially benefit from the NIC's identification of promising instructional practices in order to accelerate improvement in other schools and classrooms. This chapter examines the formal and informal ways in which the Better Math Teaching Network worked to spread its impact in Year 2. Many BMTN teachers have engaged in informal spread to other math teachers individually and in department meetings at their schools. In these interactions, teachers tend to spread math-specific aspects of the work and ways to integrate improvement science into practice. In addition to informal spread, BMTN network leaders designed three formal mechanisms for the network to spread its impact, including:

- Creating a public face of the network via Facebook, a website, and a monthly newsletter.

- Encouraging BMTN teachers to present to the broader math education community via conference presentations and blogs.

- Establishing a parallel network of school, district, and state math leaders (a leader network).

There are a variety of ways in which ideas and new learning from NICs can spread beyond network members. Network leaders must intentionally design and manage these mechanisms, which in turn will focus both the ideas that are shared (e.g., improvement science strategies, classroom routines) and the audience for whom they are intended. An important job of network leaders is to consolidate learning, package it into deliverable components, and test out successful strategies for spread.

Chapter 9: BMTN Spread: Building a District-Based Learning Community

In Year 2, Better Math Teaching Network leaders spread the work of BMTN into a Rhode Island school district. They partnered with the high school's math department chair to build a district-based learning community of middle school and high school math teachers that explored the implementation of improvement science using routines, tasks, and measurement tools tested and refined by BMTN teachers. This chapter tells the story of the first year of this learning community.

Conclusion

The Better Math Teaching Network seeks to provide opportunities to increase student engagement in high school mathematics. Teachers in the network are highly engaged; they spend time outside of their typical teaching duties to attend quarterly network meetings and engage in quarterly inquiry cycles supported by virtual small group meetings. In addition, some BMTN teachers participate in optional study group meetings, support the network through leadership roles, and spread what they are learning beyond the network. Seeking to improve their own practice, BMTN teachers learn from each other and from network leaders. As the network moves into its third full year, it is poised to consolidate learning from several years of PDSA testing, build structures to spread that learning beyond network members into their schools, districts, and new districts, and inform the field on what it takes to grow and sustain an instructionally-focused networked improvement community.

Introduction

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. **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.

> **This introductory narrative precedes every Better Math Teaching Network report, and was published in the BMTN Year One Developmental Evaluation Report, 2017, project staff: Jennifer Lin Russell, Jennifer Sherer, Jennifer Iriti, and Courtney Long.**

During the 2017–18 school year, 41 teachers from all six New England states participated in the second official year of the network's operation. Teachers were selected from a pool of volunteers that 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 ninth-grade students.[1] 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.

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1 Occasionally teaching assignments change, and in several cases, teachers returning to the network had no Algebra I sections in 2017–18.

Purpose: Student engagement in Algebra I

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 currently 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). Access to algebra content is an equity issue because students from lower-income families and those who are lower achieving 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).

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 tenants 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 examination of 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 the following: allowing for extensive 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.

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.

Strategy: Learning how to transform education through NICs

The NIC concept

The BMTN is organized as a network improvement community, or NIC for short. NICs 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; Russell, et al., 2017). In promoting the use of improvement science in networked communities, Tony Bryk and colleagues at the Carnegie Foundation for the Advancement of Teaching have 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, Yeager, Hausman, Muhich, Dolle, Grunow, LeMahieu, & Gomez, 2014). 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, Bryk, Dolle, Gomez, LeMahieu, & Grunow, 2017).

Jennifer Russell and colleagues (under review) argue that NICs aim to catalyze a community that can solve complex problems of practice. They refer to this as a *scientific-professional learning community*, a concept meant to emphasize a network's learning orientation, the collaboration among professionals that drives this learning, and a systematic approach to generating knowledge and practical improvement akin to the process utilized in scientific communities. Figure 1 represents the theory of NIC Development Framework proposed by Russell and colleagues. It details six domains of effort that are posited to be essential components of developing a network that operates as a scientific-professional learning community. This framework is a tool that guides the work of this developmental evaluation team, anchoring our tools and routines.

Figure 1: NIC Development Framework
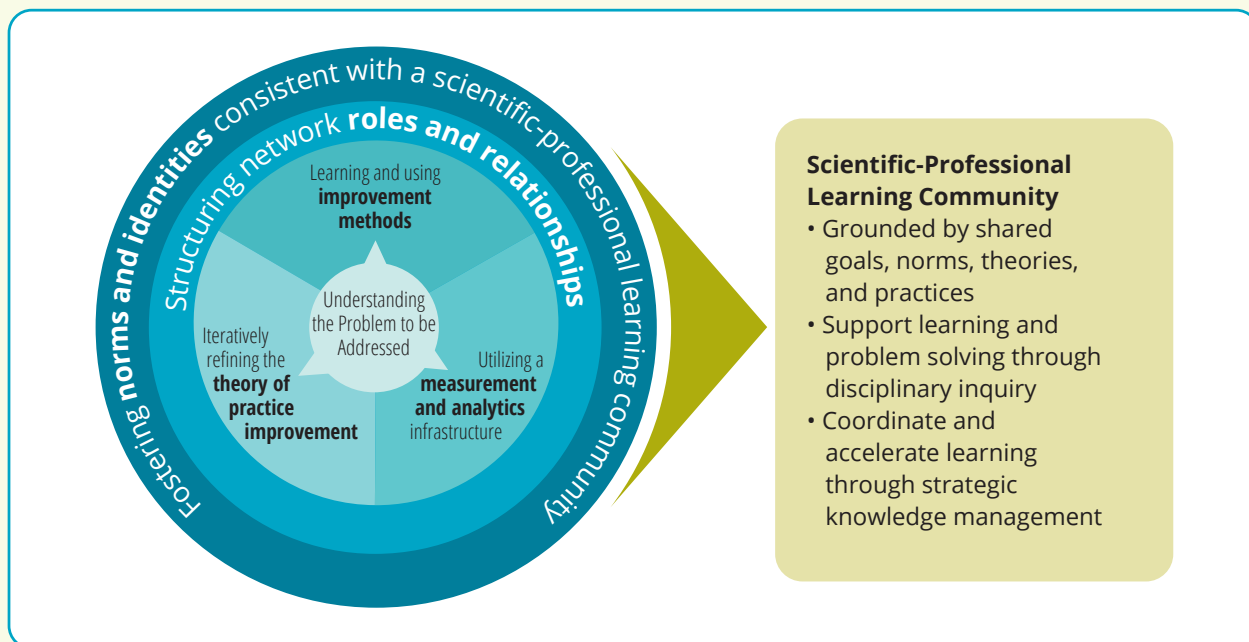
Improvement science (including quick overview of PDSA cycles)

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. It 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 teaching, to refine their joint planning time (outside the classroom), improve the roles and routines students embrace, and make changes to structures or policies at the school or system level to allow for effective practices of student-centered formative assessment.

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, 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. Identifying hypotheses, testing those hypotheses, and comparing results with one's predictions generates new insights about how to improve practice. This rapid inquiry generates new learning; testing changes in varying sites of practice creates opportunities to examine variations in context that support or constrain practice. BMTN teachers use the PDSA cycle routine to test instructional changes and to see whether they improve student-centered formative assessment practices.

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 a 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 intend to take advantage of a broad set of resources, as well as 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 (NIC) 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 (AIR) 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 and continued in 2017–18 with 41 teachers. In Year 2, the network held four face-to-face full-network meetings. During action periods between meetings, network leaders supported teachers' efforts to identify and test changes in their practice that promoted deeper engagement in algebra content. During this second 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 third full year of operation and has expanded to work with 52 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 an important milestone in students' academic trajectories. While the networked improvement community concept is rapidly proliferating the education field, many NICs have not tried to address classroom instruction, in part due to the complexity of improving teaching. In this way BMTN is an important case for the field given the critical role classroom instruction plays in improving student learning outcomes.

Recognizing both the promise and challenges of networked improvement communities to support student-centered teaching and learning, Nellie Mae 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.

This report outlines findings from the second 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 second year of operation. We drew on a range of data sources to examine this networked improvement community in action including:

- observations of whole-group and small-group network meetings;

- interviews with participating teachers conducted at multiple time points throughout the year (N=40 December; N=38 June);

- teachers' responses to a survey designed to measure teachers' experiences with key features of the NIC concept (N=41 December; N=38 June);

- analysis of teachers' formal and informal connections to one another that are facilitated by the network;

- documentation that teachers generate through their improvement cycles;

- classroom observations and follow-up interviews with a small sample of teachers;

- observations of meetings with BMTN affiliated educators (state, district, and school leaders; district-based learning community participants).

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

Organization of Year 2 Report

We present our findings as chapters, which describe key themes that emerged from our analyses, focused as follows:

Chapter 1: BMTN Routines and Tools

Chapter 2: Influence of Routines on the Collaborative Work of BMTN Teachers

Chapter 3: The Challenges of Improvement Science

Chapter 4: Challenges to Engagement in BMTN

Chapter 5: Teacher Perceptions of BMTN Impact on their Teaching

Chapter 6: Teacher Perceptions of BMTN Impact on Student Engagement

Chapter 7: Scaling the Network

Chapter 8: Spread in Year 2

Chapter 9: BMTN Spread: Building a District-Based Learning Community

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. 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. Specifically, the first two chapters reveal how network leaders design for the work and how important these designed structures are to a healthy network. Chapters 3 and 4 examine challenges teachers face as they engage in the work. Chapters 5 and 6 explore teacher perceptions of how their engagement in BMTN has influenced their own practice and the engagement of their students. In Chapter 7, we examine how the growth of BMTN has affected teacher experience in the network. We finish with a consideration of spread. In Chapter 8 we examine the different ways that the network is spreading the work and in Chapter 9 we present a case study of a learning community, which serves as one strategy for spread that the network leaders tried in Year 2.

Chapter 1: BMTN Routines and Tools

Routines and tools are often used by leaders in organizations to structure work practices and to catalyze and sustain change. In the Better Math Teaching Network, network leaders designed and refined routines and tools to support both teachers' use of improvement science and their engagement in the network. By intentionally and carefully designing these routines and tools, BMTN network leaders scaffolded teacher learning and supported teacher practice. In this chapter we examine three routines and three tools that BMTN network leaders designed and implemented. We consider each routine and tool's designed purpose. We then discuss the benefits and challenges teachers experienced as they engaged in each routine or used each tool, as reflected in our data. Finally, we note possible design implications for the field.

Network meeting routine

Designed purpose

BMTN network leaders designed network meetings that convene all BMTN teachers 4–5 times each calendar year, with one convening in the summer and the remaining occurring during the school year. These in-person meetings provided opportunities to engage in new learning; opportunities to share ideas and tools; work time to plan, design, and collaborate; and social time for all participants to connect and build trust.

Benefits

- BMTN teachers found these meetings to be the most useful element of the network in that they provided the opportunity for participants to meet face to face with each other and engage in a variety of ways (as listed above).

- Teachers appreciated the time to work together with network leaders and other teachers on their Plan-Do-Study-Act (PDSA) work. Teachers saw this as important time to get started or maintain momentum on their individual work, and easily access a range of resources and expertise.

- Teachers used network meetings to find new ideas, resources, tasks, and strategies for teaching student-centered Algebra I to ninth-graders from their BMTN colleagues.

Challenges

- Some teachers found the travel, time away from the classroom, and time away from their families challenging.

- Some teachers returning to the network found redundancy in meeting content as new teachers were onboarded.

- Interview data suggests that some returning teachers thought they were an underutilized resource in support of the learning of new members during these meetings.

Virtual small group PDSA meeting routine

Designed purpose

Network leaders placed teachers into small groups for regular coaching and collaboration meetings based on the area of focus for their PDSA work (e.g., teachers trying out changes to engage more students in making mathematical connections were grouped together). Teachers in these groups met virtually at regular intervals four times throughout the year (in between in person network meetings) to share their PDSA work, explore challenges, and receive coaching support from peers and a network leader. Over time, in an effort to scale the work, network leaders released control of the meetings to participants by giving teachers a protocol to guide their collaborative time.

Benefits

- The majority of BMTN teachers found these meetings to be important or essential to their learning in Year 2.

- Teachers appreciated the regular coaching, opportunities to check in, and the accountability that these meetings provided.

- This routine allowed teachers to become more knowledgeable about what a few of their network colleagues were working on and to exchange meaningful advice and ideas.

Challenges

- While most teachers found the PDSA meetings useful, those who reported lower utility tended to report a combination of challenges, such as inconsistent participant attendance, unprepared group members, lack of a common focus among group members, participants

with very different school contexts, and/or groups that lacked the expertise to support their growth.

- While many teachers thought the PDSA group meetings held without a network leader went smoothly, there was agreement that coach participation was critical in the early stages of the work, is likely critical throughout the year for groups with all new teachers, and added depth to the discussions which was valued by all groups.

- Most teachers noted that it was at least slightly challenging to find time to meet virtually with their PDSA group, in part because teachers have different school day schedules, open periods, and responsibilities after the school day.

Optional virtual study group routine

Designed purpose

Optional virtual study groups, focused on specific math content, were a new routine BMTN network leaders added in January of Year 2. As one hub leader reflected, "We added study groups to support teachers' understanding of 'depth.' To really know what we mean by a deep connection, for example, they needed to have a deep understanding themselves." The routine was designed to build content knowledge, pedagogical content knowledge, and to support disciplinary-focused collaboration. Network leaders selected texts, designed a protocol, and created groups of 3–4 teachers, with groups formed based on teachers' choice of text and scheduling availability. Groups met to discuss one or two chapters of their book at a time; this meant that most groups met 6–7 times from January through May, approximately every two weeks. Twenty-four of the BMTN teachers (59 percent) chose to join a study group.

Benefits

- Both new and returning network members found the study group routine to be very valuable.

- The greatest benefit noted in interviews was the value of working with other teachers. Reading about a math topic and discussing it with other math teachers provided a sense of belonging to a mathematics community, which is what many teachers who joined the network sought.

- Other benefits that the study group teachers reported in interviews included building teacher knowledge and acquiring new resources.

- Ninety percent of participating teachers indicated that they took something they learned in their study group and put it into practice [but not necessarily within their PDSA cycle] this year or would use it next year.

Challenges

- The biggest challenge teachers noted was difficulty finding time within their existing professional demands to meet with the group and the logistics of scheduling the meetings given the range of availabilities.

PDSA template tool

Designed purpose

Teachers in BMTN documented their inquiry cycles on a template that network leaders modified from the standard form used by the Carnegie Foundation for the Advancement of Teaching. The template frames the work in very specific ways:

- It is organized by the four stages of the cycle (Plan-Do-Study-Act), signaling what specific information teachers should think about and fill in during each stage of their inquiry cycle.

- It focuses teachers' inquiry by having them fill in predictions and data for three questions: Will I implement the routine as planned? Will students engage in the routine? Will they engage with depth/quality?

- Teachers archived their PDSA documentation in Google Drive. They embedded links to other relevant documents (e.g., measures used, student work, and compiled student data) so that network leaders and teachers have access to each other's work.

Benefits

- The template structured each step of the PDSA cycle for teachers, prompting data capture, analysis, and reflection.

- Sixty-five percent of teachers thought that their PDSA documentation allowed them to accurately represent their work. These teachers thought the form served to structure their work and captured their practice so others could see it.

Challenges

- Thirty-five percent of teachers either did not think the PDSA documentation allowed them to accurately represent their work or they were not sure. Teachers in this category noted:

  - They often left things out of their documentation (e.g., learning was not well represented because of a rush to meet the deadline).

  - They were not able to capture their thinking/process in the template structure.

  - They were not able to document the dynamic work processes of the classroom.

  - They were not as reflective as they had hoped to be.

- Teachers reported that the template was long and required attention to detail. Some teachers reported that completing the form was time intensive.

  - This created a tension for these teachers between the detailed work of documentation and time to reflect.

  - In some cases, teachers struggled to complete the form in real time, and consequently depended on memory to populate parts of the implementation and data reporting sections.

- While the template structured important elements of continuous improvement, some teachers struggled to fill in parts of the form where their knowledge of continuous improvement was still relatively nascent:

  - Making predictions and comparing results to those predictions

  - Aggregating data across trials

  - Articulating how their changes led (or did not lead) to improvements

Student survey

Designed purpose

Network leaders designed a student survey tool to measure network progress toward BMTN's aim. Administered two times each year,[2] students reported on how often they engage in different aspects of *connect*, *justify*, and *solve* (the three focal areas of deep engagement in algebra, as defined by the network).

Benefits

- Teachers reported this tool helps them stay more accountable to the aim and helps them intentionally design more activities that align with student-centered teaching and deep engagement in algebra. The tool is potentially a mechanism for encouraging teachers to implement student-centered practices beyond their PDSA cycles.

Challenges

- Teachers with inconsistent attendance, high student turnover, and/or different student populations for terms one and two wondered whether the trends noted in the data were accurately reflecting meaningful changes in student engagement. And so, overall, they wondered whether they could trust it as an indicator that their changes were leading to improvements.

Change idea summary template

Designed purpose

Network leaders designed two templates to support year-end reflection and to scaffold how BMTN teachers share their learning with the rest of the network. This was also a tool to help network leaders consolidate learning.

- First, teachers populated a PowerPoint template by identifying the following elements:

  - Overview (DEA: *Connect*, *justify*, or *solve*; type of routine; unit/lesson timing)

  - Problem they were trying to solve

  - Change idea

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2   Some of the teachers who began new classes (and thus had new students) second semester gave the survey more frequently in order to capture pre/post data with each group of students.

- Key learnings

- Final routine

- Resources to support routine

- Measures of engagement and deep engagement

- Rubrics, results, student work and/or final thoughts, and next steps

At the May network meeting, teachers presented their work to small groups of network members using this slide deck.

- Second, teachers filled in a template that became part of a year-end book of change idea summaries that gets shared network-wide in the subsequent summer meeting with all new and returning teachers. The template included the same elements as the PowerPoint template, and the following additions:

  - Evidence of promise for the efficacy of the change idea

  - Description of the context in which they teach

Benefits

- Teachers found the change idea summary tools to be very helpful in supporting year-end reflection and learning across their individual PDSA cycles and templates.

- Teachers appreciated learning from each other's presentations in May, and some used the change idea summary book as a way to learn from others. Roughly a third of the teachers used the book as a way to introduce themselves to the work. [See Figure 2 below. Note: Some teachers may have perused the change idea summary book but not used it at all or not in any of the ways listed. These teachers would have selected "none of these options."]

Figure 2: Ways BMTN teachers report using the Change Idea Summary Book in Year 2

Chart data:

Category	New Teachers	Returners
None of these options	40%	40%
It helped me get a sense for the work	30%	27%
I edited a change idea, task, or measure from it	10%	13%
I used a measure from it	10%	7%
I used a task from it	10%	7%
I used a change idea(s) from it		7%
It helped me connect with other teachers doing similar work		
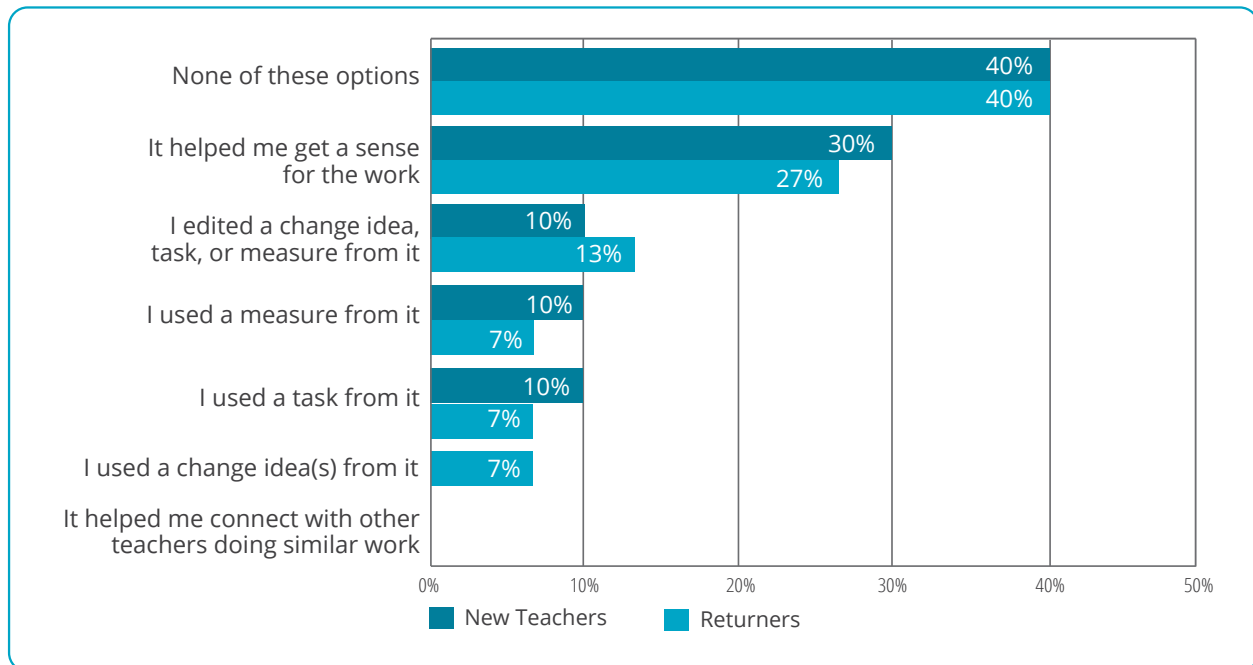
Challenges

While the book served as a good introduction to the work, teachers rarely used it to identify a change idea or connect with others doing similar work, uses that might accelerate learning in the NIC. See Figure 2 above.

Implications

In BMTN, routines and tools helped network members navigate new learning and supported them in changing their teaching practice to improve student engagement. Routines and tools thus serve as a mechanism that network leaders can design and redesign as they support growth and change of individual members and the network as a whole.

- Routines that were most effective involved regularity, collaboration, and opportunities for learning.

- Balancing less frequent in-person and more frequent virtual meetings can support momentum, accountability, and engagement.

- Simple tools work well for busy teachers, as does building in time for structured or guided reflection.

- Finding ways to capture and consolidate learning from inquiry cycles is a persistent challenge for networks.

In the next chapter, *Influence of Routines on the Collaborative Work of BMTN Teachers*, we focus on specific ways in which routines support the collaborative work in BMTN, and how critical the design of these routines is to the health of a network.

Chapter 2: Influence of Routines on the Collaborative Work of BMTN Teachers

Network leaders designed and refined a series of tools and routines to support participant learning and engagement in the Better Math Teaching Network (see *BMTN Routines and Tools*). Three of these routines—often referred to as "participation structures" in networked improvement communities—organized the collaborative work of BMTN teachers: network meetings, PDSA meetings, and optional study group meetings. In this chapter, we examine the importance of these routines in building and sustaining collaboration, an element critical to accelerating learning in networked improvement communities.

In addition to creating spaces for teacher collaboration, network leaders designed each of these BMTN routines to have a specific learning purpose as follows:

- Network meetings:

  - Early in the year, the meetings focused on building common language and understanding of the aim (defining deep engagement in algebra) and the network's methodology (iterative improvement cycles, the PDSA).

  - Later in the year, the meetings focused on sharing learning and the consolidation of individual learning.

- PDSA meetings: Teachers shared individual PDSA work and got coaching support from a network leader and other group members.

- Study groups: Teachers built content knowledge and pedagogical content knowledge.

While nearly all BMTN teachers found these three participation structures valuable to their learning at some level, nearly three-quarters found the whole-group meetings to be essential. See Figure 3 below.

Figure 3: Teacher perceptions of importance of participation structures for their learning[3]
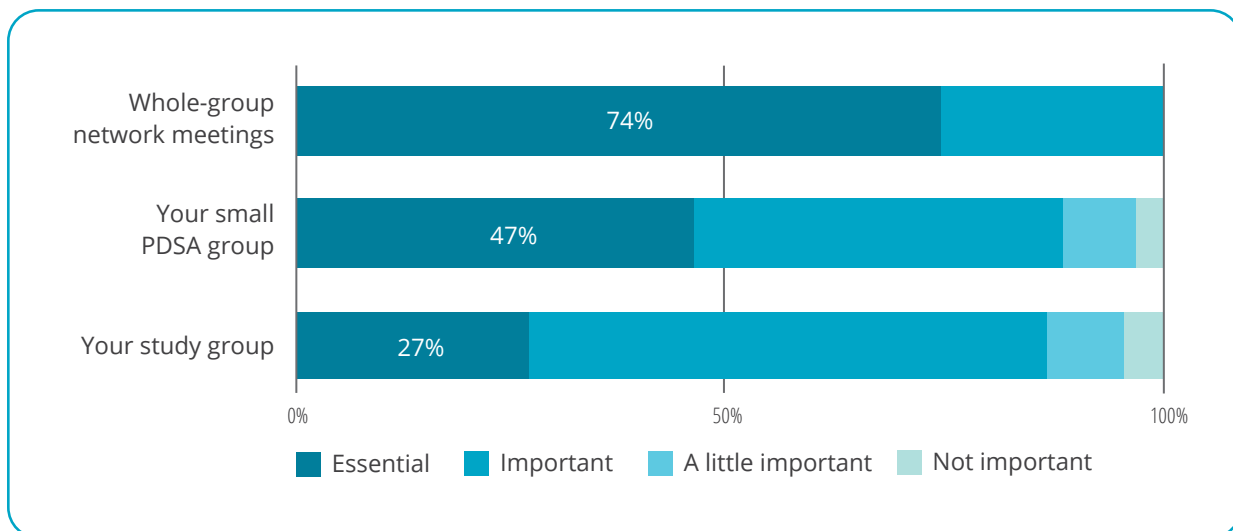
In addition, when asked about the adequacy of time for engaging in each structure, all teachers who participated in an optional study group thought the interaction was just right and nearly two-thirds of all BMTN teachers thought that their interaction with their PDSA group was just right. However, over half of BMTN teachers would have liked more whole-group network meetings. See Figure 4.

Figure 4: Teacher perceptions about the amount of interaction in each structure

The majority of teachers felt the amount of interaction with their small PDSA group was '**Just right**'

61% 39%

A little over half of teachers felt the amount of interaction with whole-group network meetings was '**Not enough**'

53% 47%

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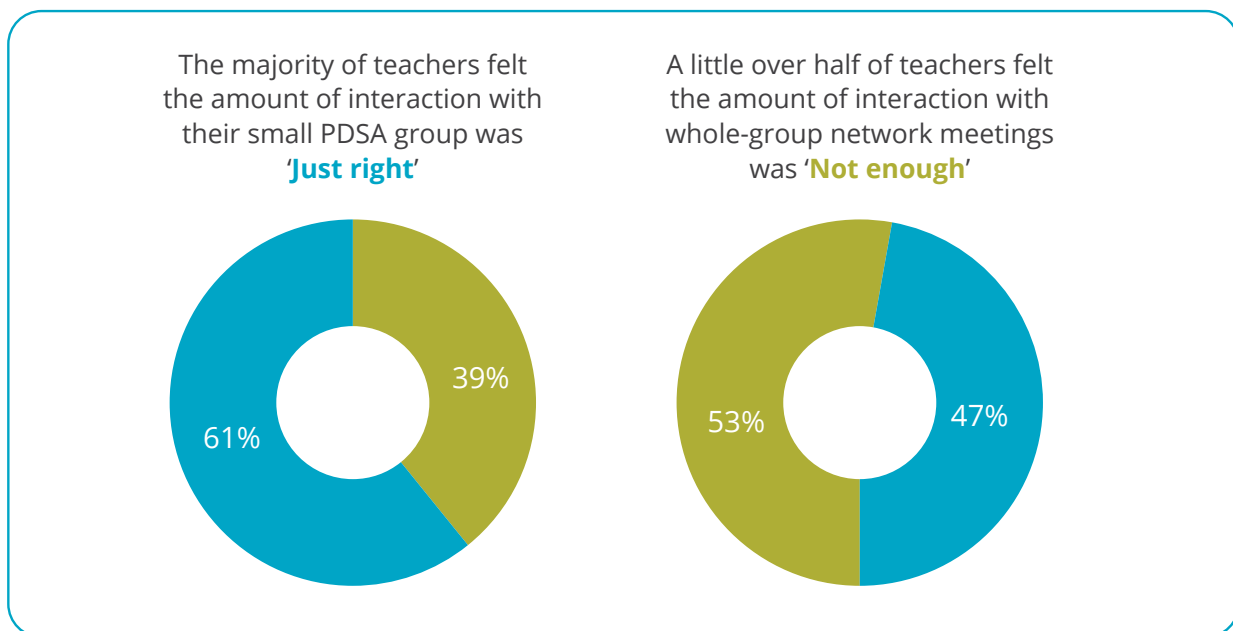
3   In all, 24 out of 41 BMTN teachers chose to participate in a study group in Year 2. Percentages of study group responses are for N=24.

While BMTN teachers learned about the network's aim and methodology during network meetings, many teachers used network meetings as opportunities to connect with other math teachers and learn about new methods, tasks, and classroom activities. This network structure is also the only one that is face to face; the other meetings take place virtually. Some teachers also noted that network meetings filled a collaborative need that was missing from their home school contexts.

Almost half of the BMTN teachers deemed PDSA groups as "essential." For some, these groups offered support and accountability that helped them maintain momentum and stay on track.

> " *I love meeting with my PDSA small group. I felt like being a new member, I think I needed a bit more regular, consistent support. Whenever I met with my PDSA small group, I left with a clear vision of next steps and where I needed to go with my testing. I would love more opportunities to do this."*

> " *I think for me the accountability piece to meet in the PDSA groups more often is a little bit better because I know I have to have this done by that next meeting. I think that might have helped keep me on track a little bit better."*

> " *Our small-group meetings were great because I would want to go into those meetings with everything current that I had."*

Teachers who found the PDSA groups to be less important to their learning cited the following reasons: there was a lack of expertise in their group, members were not prepared for the meetings, and lack of participation (attendance) in the meetings. Thus, monitoring PDSA group *health* and intervening as warranted could be an important network leader function when such participation structures are used.

Teachers who chose to be involved in study groups were overwhelmingly positive about the experience, even though the time demand was high: groups met 6–7 times, approximately every other week, and required additional work beyond the PDSA cycles that teachers were already conducting in their classrooms. Teachers reported the key benefits of the study groups to be working with other teachers, building teacher knowledge about specific math content, building student knowledge, and acquiring new resources. In the spring, as the frequency of other network participation structures decreased (due to a weather-related cancellation of the March network meeting and a decrease in frequency of spring PDSA meetings), study groups likely filled the collaborative void for many teachers.

Overall, teachers emphasized the value of collaborating with other teachers through network structures. For example, one teacher described the value of these designed collaborative spaces saying:

> **"** *I think about how powerful the collaboration is. Even when we're not able to meet in person, but to have the smaller groups and the designated time to really focus on practice... Having like-minded people to talk to, people that are passionate about student learning, and focused on student-centered(ness) is really powerful."*

In order to further explore teachers' collaborative interactions in the network, we examined patterns of connections among participating teachers using social network analysis. Given that teachers place a high value on collaborating with one another through network structures, and a significant proportion of teachers had been in the network for multiple years, we wondered whether these connections might extend outside of formal participation structures. Analysis of the data suggests that this is not the case, at least on a large scale. While some deep connections have likely been established among subsets of teachers in BMTN, in general, collaboration among BMTN teachers happens primarily within the structured interactions and not informally outside of these designed participation spaces. Figure 5 shows maps of interactions among BMTN teachers. The map on the left shows the connections that occur within designed collaborative spaces and the map on the right shows the connections that occur outside of formally designed spaces. Notably, 27 percent of teachers who responded to the survey do not interact with anyone else outside formal network structures. This suggests that the designed participation structures are critical to the network because they determine with whom and how intensely teachers collaborate with one another.

Figure 5: BMTN teacher connections from formal structures (left) and BMTN teacher informal connections (right) [4]
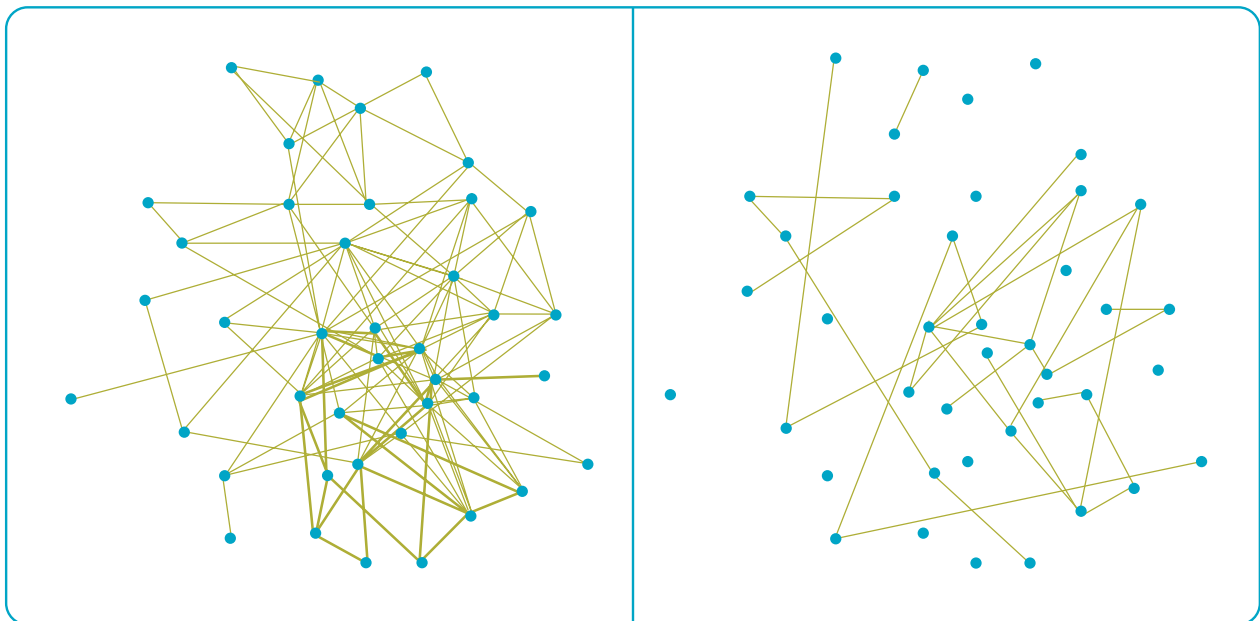
4   Left map: Formal structure connections: PDSA small group, Study group, DEA time, and independent time (DEA/independent were combined, then only kept reciprocal ties). Right map: Outside of formal structure connections, reciprocal ties: email, phone, and in person.

Several teachers reported a desire to have additional interaction with other teachers but reflected on the difficulty of reaching out beyond scheduled meetings. For example, one teacher described the challenges,

> *I tried to look through [Google] folders and reach out to some of the other teachers. But everybody's busy, and I didn't get a whole lot back."*

Another shared,

> *I wish I had taken advantage of my colleagues in the network more because I think that would've helped keep it on my radar. You always have a to-do list of things that you have to do and if it's not something you are talking to everybody about all the time, it tends to get pushed to the bottom of the list. I feel like I did that too much."*

Some teachers noted their desire to work more with others but acknowledged that teachers are busy.

> *I feel like I still have so much to learn, and I guess that's probably been my biggest challenge. I'm the only teacher—some teachers have another person in the network who's also in their district, and so that close proximity to another teacher has allowed them to be able to work together and to bounce ideas off of each other. But I didn't have that, so sometimes I felt that I really just wasn't sure what I was doing was right, and that didn't feel good. It's hard to feel like you don't know if you're doing the right thing. … I think a part of it is probably just me reaching out. Like when I'm feeling like, "Oh, I could really use some help," maybe trying to reach out and get that assistance on my own. But it's hard, because everyone is so busy."*

These teacher perceptions partially explain why designed collaborative spaces are so crucial for supporting sustained interactions within a network of educators.

Implications

- Teachers lives are busy. Even when they are deeply committed to a network and the work involved, their collaboration is likely to be largely dependent on formally designed and implemented participation structures that organize meaningful work.

- Although in-person meetings are resource intensive, teachers see face-to-face time as critical to the work. These face-to-face meetings build and maintain trust, motivation, and learning.

- Given that participation structures largely shape the collaborative work that teachers do, network leaders must intentionally design them to achieve network goals.

Chapter 3: The Challenges of Improvement Science

Learning and integrating improvement science into practice is the biggest challenge teachers face as they engage in the Better Math Teaching Network. In end-of-year interviews, 53 percent of teachers who had been in the network more than one year and 78 percent of teachers new to the network identified an aspect of improvement science as one of the most significant challenges they encountered as they engaged in the work. Most often, they spoke about challenges with data and measurement. Survey data support these patterns, as is reflected in Figure 6 below.

BMTN teacher challenges with the PDSA process

Legend: Very challenging | Moderately challenging | Slightly challenging | Not at all challenging

Challenge	Very challenging	Moderately challenging
Collecting the right kind of data to judge whether my change idea worked	45%	39%
Identifying practical measures that measured my change idea	37%	42%
Consistently completing the PDSA documentation	16%	45%
Articulating my questions	8%	26%
Collecting enough data to make informed decisions	8%	45%
Making predictions	5%	18%
Reflecting on what I learned from the data	3%	24%
Using data to drive decisions on my next steps	3%	26%
Connecting my data to my predictions		22%
Identifying a change idea		39%

Teachers also described identifying good change ideas and integrating improvement science work into their practice as teachers to be challenging. Some teachers mentioned not remembering to do the new routine or simply struggling to fit it into the flow of their classroom instruction.

Typically, the first year of integrating improvement science into practice is difficult for teachers. As BMTN enters its third year, our interview data clearly indicates that teachers new to this work initially struggled, but after a year of doing the work, they were much more confident engaging in inquiry cycles. Almost half of teachers still indicated in interviews that some aspect of improvement science is challenging, even after their first year.

> ❝ *There was a huge learning curve last year. And this year [the PDSA cycles] felt like part of my practice. This is just what we do."*

Another teacher expanded on this shift,

> ❝ *It made it so hard for me that first year to come up with a change idea, collect some information, make a decision, and either embrace it, tweak it, or move on. This year was quite different. I feel like I was able to more swiftly move into and out of change ideas."*

Once teachers became accustomed to engaging in inquiry cycles, some aspects of improvement science became less challenging for them. For example, once teachers engaged in a full PDSA cycle, they began to understand how to identify a change idea, go through the different steps of the cycle, and document their work. However, issues around data collection and measurement persisted into teachers' second and third years of participation in BMTN, indicating that this challenge is harder to solve than teachers learning to integrate inquiry cycles into their practice over the course of their first year.

Using practical measures in the context of disciplined inquiry cycles is a critical component of continuous improvement work (Bryk, Gomez, Grunow & LeMahieu, 2010; Yeager, et al., 2013). Practical measures are measures that operate at the level at which work is carried out. They are "practical" in that they can be collected, analyzed, and used within the daily work lives of practitioners. They are also "practical" in that they measure practice. Practical measures are used to learn whether the changes introduced are improvements.

Challenges associated with designing, collecting, and using practical measures were frequently noted in interviews with BMTN teachers and supported by our analysis of their improvement cycle documentation. Below, we outline three challenges teachers experienced as they worked to design, implement, and use practical measures in the context of PDSA inquiry cycles. These three challenges were designing practical measures for algebra engagement, collecting and analyzing practical measure data, and interpreting the findings from their data.

Challenge #1: Designing practical measures of algebra engagement

Network leaders and teachers co-constructed definitions for each area of focus (*connect*, *solve*, and *justify*) and network leaders shared a "continuum" for *justify* and *solve* in the summer prior to the beginning of PDSA testing. Teachers then borrowed from these resources to design their own practical measures or worked with colleagues to design measures. See Figure 7 below.

Origins of practical measures for PDSA cycles

Origin	Percent
Built it myself	74%
Co-constructed with BMTN collegue	63%
BMTN in-person meeting	45%
BMTN teacher in my virtual PDSA group	42%
BMTN teacher not in my small group	24%
BMTN Change Idea Summary Book for Year1	18%
BMTN virtual small group coaching meeting	18%
BMTN Hub leader	18%
Measures: Research	13%
BMTN teacher in my study group	13%
Other	8%
TRU math rubric	8%
Co-constructed with non-BMTN colleague	5%
Colleague from outside of the BMTN	3%
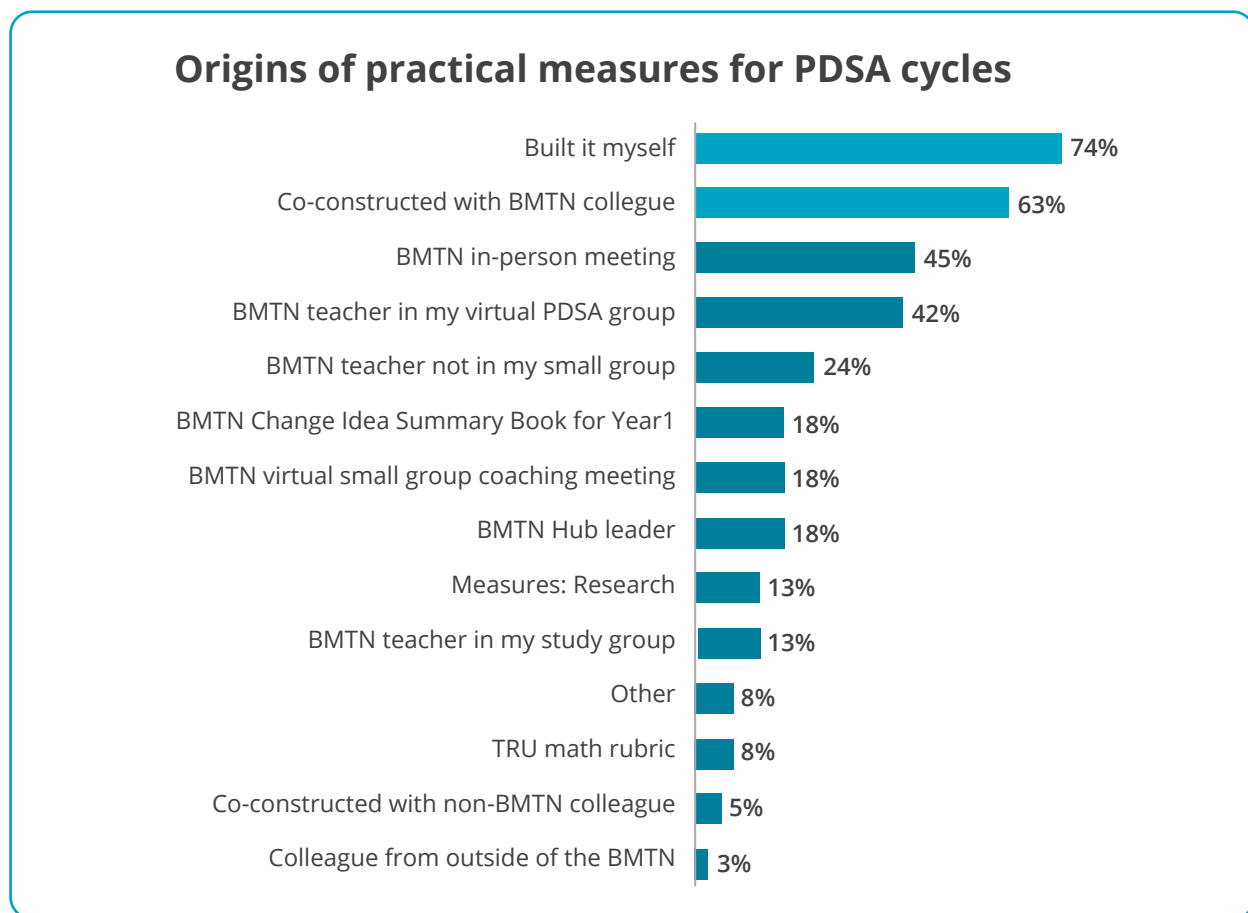
Network leaders encouraged teachers to think about engagement in two ways: are the students engaging in the work (e.g., are they doing the task?) and then, are the students deeply engaging in the work (e.g., are they doing the task with quality?). For this reason, most teachers built different measures for *engagement* and *deep engagement*. We examine these measures through the lens of our analysis of their change idea summaries—the documentation they crafted at the end of Year 2 to summarize their PDSA cycles.

- Engagement: Teachers typically measured engagement by using a binary method: 75 percent of teachers who included an engagement measure used yes/no indicators for *engagement* (e.g., assignment/activity attempted) while the remaining 25 percent used some type of scale (e.g., 1–4 scale).

- Deep engagement: The network defined deep engagement in three ways—*solve*, *justify*, and *connect*—and collectively built specific definitions for each of these "DEAs." These definitions served as a framework for many of the practical measures that teachers designed to measure *deep engagement*. More than three-fourths of teachers (82 percent) who identified deep engagement measures used a rubric to measure *deep engagement* at different levels for varying criteria, while 15 percent used a teacher checklist to measure *deep engagement* as a collection of yes/no indicators.

Building measures was a frustrating experience for many BMTN teachers, due in part to their lack of training to design measurement tools. One teacher reflected on this challenge in an interview:

> " *Finding a way to collect data that wasn't skewed was a challenge. What did I consider quality justification? I think they talked deep justification. When I heard students speak [I would ask myself], when did I hear it and how many times did I hear it? Did you do deep justify once? Did you deep justify twice? It was really hard to capture that and tally that.*"

In this vignette, we see how one teacher grappled with measuring quality justifications.

Vignette 1: Experienced, student-centered teacher digs deep into student thinking

Joy teaches in a rural Vermont high school. Already an experienced and highly student-centered teacher, she joined the network to work with motivated teachers from other contexts so that she could continue to be exposed to new ways of thinking and working. Joy began her testing this year focused on the use of structured math talk to support students in justifying their reasoning around rules of exponents.

Structured math talk includes partner work on a set of problems and then an exchange of the written partner work with another pair providing written feedback on their work. During this partner talk, Joy observes the student thinking evident within their discussions and written work. She uses what she observes to strategically highlight critical misunderstandings or questions with the whole class and have students help each other,

> *I write that down [student misconception] and I raise it in the whole group. I have a kid who says, "Aren't we allowed to multiply exponents?" so we justified why you can multiply exponents. But it's at their questions and it is said in their words and they love to see it up there [on the board] because I'm not the one telling them. I'm not the one doing the work. They are doing the work. They are asking the questions. They are coming up with all the stuff and it's really—that has changed my teaching so much because it's all about them.*

Within this change idea, one of the key issues that Joy has grappled with is how to conceptualize and measure a quality justification,

> *We have this rubric about what a quality justification is. But it hasn't really—the rubric has not been super helpful for me to decide if it's a quality justification. What is a very good, easy measurable way to note what makes a good quality justification? I asked my math coach and she very easily said, a good quality justification shows that a student can do something in at least two different representations. So if they can graph it and solve it and show you the connection between those two, that right there is a good quality justification. If they can show you in the table of values and they can solve it, that's a good quality justification.*

Joy began working more intently on how students think through and use representations in their efforts to understand math and to justify their work, with an eye toward students' use of two or more representations as evidence of justifying with quality. Joy used a subsequent PDSA cycle to think more deeply about how she can encourage flexible thinking and the use of multiple representations to strengthen students' ability to justify their thinking with quality. The BMTN experience provided Joy with a structured and supported opportunity to delve deeply into her students' thinking as well as how mathematics understanding can be identified and evaluated.

Challenge #2: Collecting and analyzing practical measure data

Once a teacher identifies or designs a practical measure, she has to integrate its use into her classroom and professional routines. Since engaging in PDSA cycles requires small changes and a quick assessment of those changes, the data collection, analysis, and reflection ideally takes place in a short window of time. Teachers face many challenges accomplishing this quick turnaround. Common interruptions to class time also disrupt the inquiry cycle (e.g., weather, assemblies, sickness, inconsistent attendance). As one teacher noted:

> *When ordinary things happen within the school year it throws your schedule off, it throws everything off, especially with the pressure I was putting on myself to get a certain point. Finally, I had to accept [that] it was okay to do two test rounds of the PDSA cycle and then I needed to move on."*

Recording and reflecting on the data takes extra time teachers may not have on a regular basis. In some cases, teachers did not record, analyze, and reflect immediately; in these cases, they relied too much on memory to reflect on the efficacy of the test of their change idea. Since our minds filter observations, our present observations are affected by past observations (Langley et al, 2009). When teachers relied on memory, they may not have been reflecting on what occurred but what was most present. In this way, if teachers were not relying on actual data, but reflective constructions of what happened, they were not likely to benefit from the evidence.

In other cases, when they got busy, teachers tended to let the documentation slip. As one teacher shared:

> *I was so busy this spring I found it hard to keep up with the work for the first time. My change idea was around [justify], and I did a lot of that this year, but it was hard for me to document it all. I can see this year a little differently: one part is doing the work and implementing an idea in your classroom but another part of it is analyzing and documenting that work. That second piece became more challenging for me, particularly this spring."*

In some cases, the nature of the kind of data that teachers collected to assess students' deep engagement in algebra posed a specific challenge. Given the nature of the practices they were trying to promote (e.g., justification), teachers sought to analyze student writing or student talk, which is naturally time intensive and difficult to integrate into the regular teaching rhythm.

> 66 *That was really overwhelming to me to listen to eight different conversations or nine different conversations. Even as I was moving about the room, I couldn't spend enough time with one group—in my opinion—to get good data. So, the whole listening piece was a challenge for me, and that was a little disappointing because although I was successful with the students' writing and I think that was helpful and there was growth there, we do so much more talking in math class than we do writing. I was really hoping to improve their discussion skills as opposed to their writing skills."*

Due to challenges with collecting and analyzing data on talk, teachers often ended up with data that was not measuring what they had hoped to measure. For example, by narrowing their focus to writing about math because collecting student talk was too cumbersome, some teachers found themselves unable to capture how students were justifying their ideas through talk. This became a sticking point for many teachers focused on *justify*, especially teachers with English language learners. Typically, students are more able to talk about their ideas than write about them, particularly when they are building new understandings of complex ideas.

Challenge #3: Interpreting and using data

Once teachers had their data, and even after they had done some initial analyses of the data, some felt uncertain about how to interpret the results. For example, some teachers noted that they struggled with knowing how to see trends across PDSA trials. About 15 percent tracked some measure of *engagement* over time. About 25 percent tracked changes in a measure of *deep engagement* over time. But looking at trends in data over time was hard for other teachers. Some challenges included:

- When the task differs so much as to influence student performance, teachers struggled with knowing how to compare two sets of data.

- When teachers scored different sections of their rubric for different trials, they could not compare the scores across trials. For example, in Trial 1 a teacher might focus on only one aspect of *justify*, and then add other aspects to consider for subsequent lessons.

One teacher described her uncertainty in this way:

> 66 *I think my biggest struggle is that it took me close to the end [of the year] before I really understood that I was looking for a measure that said yes or no, the kids had deeper engagement. I've been collecting all these little pieces of things and then I'd look at my data in the past and I was like, "So, what does that tell me?" I never put any end measure like, "If they do this, this, this, and this, this is what I'm calling deep engagement." I just kept collecting these separate little nuggets of information and then looking at it saying, "I don't really know what this data is telling me."*

A related challenge that emerged as teachers were trying to track changes in student engagement had to do with inconsistent student attendance. Several teachers noted it was hard to make judgments about changes due to inconsistent student attendance. This made it unclear whether variations in data from one trial to the next reflected a meaningful change or simply different student contributions to the data set.

A key component of improvement science is "learning your way to improvement." This, quite literally, means a teacher will use the data from her practical measures to determine if the small tests of change led to an improvement. In their change idea summaries, very few BMTN teachers reflected that their change had led to an improvement. It is possible that for some, the changes did lead to improvement and they simply did not record this on their final reflection.

Lack of common practical measures may limit network learning

BMTN teachers saw many potential benefits of using common measures. They noted how it might streamline the process or build a stronger basis for collaboration with other teachers. They did not yet know how to build them, indicating a possible area for network growth. Several teachers noted their desire for common measures in the network. In this sense, the diversity of measures used might be contributing to the difficulty teachers had understanding the work of others and building upon it.

> 66 *If we had a standardized rubric, would that make it less messy? Sometimes when we get together, we have five different rubrics, and they may not be evaluating the same justifying topics, the same solving topics, or the same connection topics. I wonder if we streamlined, if you would get similar data?"*

It is possible that consistency of rubrics would help BMTN teachers understand each other's practice and use each other's change ideas more often. As one teacher reflected,

> 66 *I wonder if it would be a good idea for all of us to use the same rubric—[if we had the] same rubrics for engagement and it was [a measure of] group engagement or discussion—just so that we don't have to flip back and forth between people's rubrics to see, "Oh, what is engagement? What does that look like?" It can just be standard."*

Identifying a set of truly practical measures that teachers can use to measure key aspects of deep engagement—*solving*, *justifying*, and *connecting*—may then support both teachers' continuing use of improvement methods to learn how to better engage students and the depth of their collaboration with colleagues.

Implications

- Network leaders may want to consider ways to build common practical measures and support teacher groups as they make sense of the data they collect from common tools. Indeed, finding ways to support teachers to understand and interpret data from different measures may be an important element of NICs with members who are not trained in measurement.

- In networks where members are building their own measures, network leaders may want to support teachers in understanding the difference between measurement and practical measurement.

Chapter 4: Challenges to Engagement in BMTN

When engaging in an endeavor as ambitious as a networked improvement community, network members naturally face challenges. Primary challenges reported in the Better Math Teaching Network's second year generally fell into two categories: those related to the integration of improvement science into their practice and those related to their network participation. In addition, teachers who were new to the network identified different challenges than the teachers who were returning. In this chapter we focus on challenges as they relate to teachers' network participation (i.e., network meetings and logistics of doing the work). We begin this chapter with a consideration of how time and context are challenges for BMTN teachers. Teachers new to the network had some unique challenges, which we then examine. Aside from the challenges of time and context, teachers returning to the network struggled with less access to coaching from network leaders, which was not surprising as leaders redistribute finite resources in a growing network.

Time

When interviewed at the end of Year 2, BMTN teachers often identified time constraints as the most significant challenge encountered in the work of this network. BMTN teachers struggled to find time to integrate the additional work into their practice. This includes time spent:

- in meetings (network meetings, PDSA group meetings, optional study group meetings);
- traveling to network meetings; and
- collecting, analyzing, and documenting inquiry cycles.

As one teacher shared,

> 66 *A challenge was time—it's very time-consuming. It took a lot of my time."*

Many BMTN teachers are involved in other professional activities in addition to their classroom responsibilities, and many have young children. These time challenges are reflected in interview data as well as survey data. See Figure 8 below.

Figure 8: Challenges related to BMTN teachers identified in Spring 2018

BMTN teacher challenges to network participation

Legend: ■ Very challenging ■ Moderately challenging ■ Slightly challenging ■ Not at all challenging

Challenge	Very challenging	Moderately challenging
Balancing BMTN work with your other professional responsibilities	14%	57%
Time spent doing PDSAs	8%	43%
Communication and clarity about expectations for your work in BMTN	5%	35%
Finding time to meet with your virtual study group	6%	33%
Time required for participation in network meetings & events	3%	30%
Finding time to meet with your virtual PDSA group	5%	22%
Logistics of participation in network meetings (e.g., travel, scheduling)	5%	16%
Interpersonal challenges in your virtual small group (can be any group this year)	11%	
Willingness of your virtual small group members to participate (can be any group this year)	6%	

It is notable, however, that despite the time challenges, the majority of BMTN teachers persist in the network and opt to return the next year. In this second year of the network, half of the teachers chose to join study groups, which required allocating additional time to network activities. Therefore, despite their perceptions of time challenges, many teachers are finding ways to continue to actively engage in the network.

Contextual fit

Another challenge BMTN teachers identified in interviews was the challenge of fitting this work into their teaching context, particularly with regard to curricular constraints. Some BMTN teachers identified challenges related to experimenting with practice changes given the constraints of mandated curricula, pacing guides, and district expectations for content coverage. One teacher explained, "It was challenging to fit it into our curriculum. We have a very regimented curriculum in terms of pace for the things we need to get through." In the following vignette we show how one teacher found a way to successfully integrate student-centered engagement within significant curricular constraints.

Vignette 2: Overcoming context constraints to incorporate more student-centered practices

Matt's math classroom is governed by a department-wide curriculum and assessment timeline that often constrains what he feels he is able to do. Sticking to pacing for unit assessments makes efficiency a key factor in decisions about teaching approaches. Participation in the BMTN helped him transform his previously very teacher-centered test preparation routine into a student-centered formative assessment experience.

> *I would say that the level of math talk in my classroom increased with this change idea versus the traditional way of implementing checkpoints. In the traditional sense the students would all work individually for a certain amount of time. Then I would go up to the board and go over the answers, show the work, and tell them this is worth this many points, this is worth this many points. And then at the end I would ask, "Do you have any questions?" And the students who were willing to ask questions would do so. And the students that weren't willing remained silent and quiet. And they really weren't engaged with one another.*

He believed that students had mathematics expertise and could help each other if given the opportunity. He implemented a "tiered checkpoint" in which students worked on review problems independently, worked in pairs to discuss problems they did not understand, and then pairs joined into groups of four to further broaden access to their peers' expertise. In each of these tiered moments, students were offered opportunities to reflect on their thinking and work with others to identify and attend to areas of confusion without the teacher providing the correct answer. He did this more student-centered activity in place of a more teacher-centered review he typically used to help students prepare for assessments.

> *By doing the tiered checkpoint, at least it gave them the opportunity to talk with their partner pairs. I had students sit in two-by-twos and then in small groups. And [it] opened up a level of collaboration that I think, without the checkpoint, they wouldn't get for a review for an assessment.*

Students engaged in this routine quite regularly through Matt's PDSA trials, and the routine became second nature for the students. In the end, Matt was able to carve out a niche of student-centeredness within his fairly constrained context.

When you're doing practice and reinforcement, I feel like sometimes that opportunity [student-centered practice] is lost because we're aimed at just trying to get to the answers and making sure that the students have the solidified knowledge. But I wanted to definitely incorporate the engagement of communication, and justifying yourself, and critiquing others' work. So, I think overall, those aspects of the change idea were useful in opening up those opportunities.

After multiple rounds of PDSA trials in which Matt refined the routine, he incorporated it as part of his regular teaching practice when conducting reviews for assessments. Thus, within the fairly rigid pacing constraints in his department, Matt has provided his students with frequent student-centered experiences in order to engage more deeply with the mathematics concepts under study.

Other teachers commented on how the new practices that they were experimenting with take more classroom time, and this presses them to adjust their content pacing. A few teachers commented on how scheduling constraints made the work challenging (e.g., class period is short, class only meets every other day, they get new students every trimester).

> **"** *Our classes are only 45 minutes. It was hard to implement these new things into the curriculum that was already laid out for us, so that was certainly my largest hurdle. But once I got into a rhythm with the students and with myself in remembering all of the materials and data that I needed to collect, it became a very streamlined measure that I was able to finally manage.*
>
> *I think that the fact that we have trimesters plus a project month in between made it difficult. So, my pre-post test really is meaningless because it's a different course two and a half trimesters ago and a whole different set of students. And those kinds of things that take some time to build into a culture just don't happen at my school."*

New teacher challenges

In addition to challenges with time, context, and improvement science (discussed in the previous chapter), some teachers new to the network identified challenges in their first year that related to lack of certainty about the work and finding good math tasks. We examine each below.

Lack of certainty about the work

One-third of teachers new to the network in Year 2 identified a lack of certainty about what they were doing as they began the work as one of their most significant challenges. This is often the case as network members engage in a new, complex initiative.

> ❝ *It is confusing to know what we're supposed to do for when …. I'm an organization kind of guru. If I had received a sheet in July that stated, "On this date, this is due. On this date, this is due, and this is where you put it to actually turn it in," I think it would be better for me, to understand what's going on and then where I put it when I'm done.*
>
> *I think the biggest challenge for me was how to get started. Reflecting back on the year, I feel like September through December felt very confused and muddled and unsure of where I was going and what I was really testing. I think part of that was just being new to it. But getting started on this kind of work is kind of intimidating. That was one of the biggest challenges for me.*
>
> *At first, I didn't really know where I was going with any of it. It was like the fear of the unknown."*

Difficulty finding good math tasks

When teachers new to the network were asked in interviews what their most significant challenge was, 22 percent identified something related to math tasks. This included difficulty finding good tasks and a lack of time to search for good tasks. As one teacher noted, "It does take some time to be able to put together a good task for a PDSA. [Then it takes time] to really reflect and give the task its due diligence, to look through what you got from students based on the task you gave them."

Some teachers noted they needed training in how to identify and find high quality tasks. One teacher reflected,

> ❝ *I had a hard time understanding what kind of tasks I should be giving my students. So, there was a learning curve there. …I think we as a network should somehow share the tasks that we did in a variety of different content-specific areas. We might even show ones that don't work and spend a little bit of time explaining why it doesn't work and why something did work. I had heard a lot about low floor, high ceiling activities, but I've never had a lot of experience looking for them, finding them, using them in the classroom. I think maybe a little training on understanding how to go about finding those kinds of tasks would be very helpful."*

These teachers recognized that having good math tasks is a foundational resource for engaging students more deeply in algebra. In Year 3, the network is putting together a task library that will, in part, support this challenge.

Implications

- How might teachers in highly structured contexts select change ideas that will work within their constraints?

- How might the experience of returning teachers be leveraged to support new teachers in overcoming their most pressing challenges related to engaging in the network?

- How might the network support the use of good tasks, and support teachers in learning how to find and/or develop good tasks?

Chapter 5: Teacher Perceptions of BMTN Impact on their Teaching

Teachers in the Better Math Teaching Network (BMTN) are working toward the network's common aim: to increase the number of high school students in algebra who *connect*, *justify*, and *solve* with depth. Network leaders use their knowledge of mathematics and mathematics teaching to press teachers to consider not only whether their students are more engaged in student-centered practices around *connect*, *justify*, and *solve*, but to also consider whether their students are engaging with quality. In other words, are students doing the work (e.g., a student is justifying her answer) and are they doing the work with quality (e.g., she gives a quality justification).

BMTN teachers agree that their engagement in the network has influenced their teaching in a variety of ways. In this chapter, we briefly note the general influence that BMTN teachers report the network has had on their teaching. Next, we look more carefully at two ways in which teachers perceive BMTN had an influence on their practice: changes in instructional planning and changes in student-centered instruction. Then, we examine how those changes connect to the work that teachers were doing in BMTN—specifically their engagement in inquiry cycles.

Overall influence on practice

BMTN teachers report that as a result of their engagement in BMTN, they are more intentional in their teaching and more reflective about their practice, two key components of continuous improvement.

In addition, many of them report that they now think differently about how students learn. See Figure 9. All but one teacher who took the survey said that the network has had some impact on their thinking about how students learn.

Figure 9: Teacher assessments of extent to which network participation influenced their thinking about how students learn

Amount of perceived impact of BMTN participation on teachers 'thinking about how students learn'
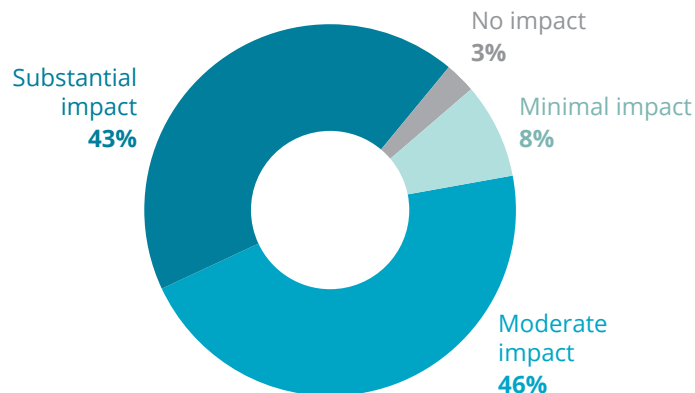
No impact
3%

Minimal impact
8%

Substantial impact
43%

Moderate impact
46%

> *We don't know a lot about learning. We're also learning, what does it mean for students to justify their thinking? That is a very, very important question. I don't think teachers generally think about that question enough."*

> *We are asking, how are kids learning to solve? How are kids learning to think? How are they learning to justify their thinking so that others want to follow them down a path? … But don't forget to get them to grapple with a problem and really try to dig in and see what they can come up. Do you recognize any patterns that you can use? How might you want to problem-solve this? Traditional math classes had nothing to do with teaching the kids to solve a problem on their own. It would be like, "This is how I did it. Now you do one that's very similar." We had kids that were very bored, and they weren't learning anything. I think that getting people to shift their perspective on what's really important is something that we are learning and hopefully could spread around a little bit. Because, apparently, all that strict instruction wasn't needed to get kids to learn. I gave up a third of my time for that and it didn't make any difference. So, I think we're on to something big there."*

These teacher quotes illustrate how BMTN is spurring teachers to think more about what quality algebraic thinking looks like and how their own actions elicit that kind of understanding.

Influence on instructional planning

Teachers perceive their engagement in BMTN had an influence on their instructional planning. Instructional planning involves several elements: teachers must identify goals for student learning, select and adapt tasks and activities to engage students to reach those goals, and structure the class time to flow in meaningful ways as students engage. All of the BMTN teachers who took the survey indicated that their engagement in the network has had some impact on how they plan their lessons, with 37 percent noting a substantial impact. See Figure 10.

Amount of impact of BMTN participation on how teachers plan their lessons
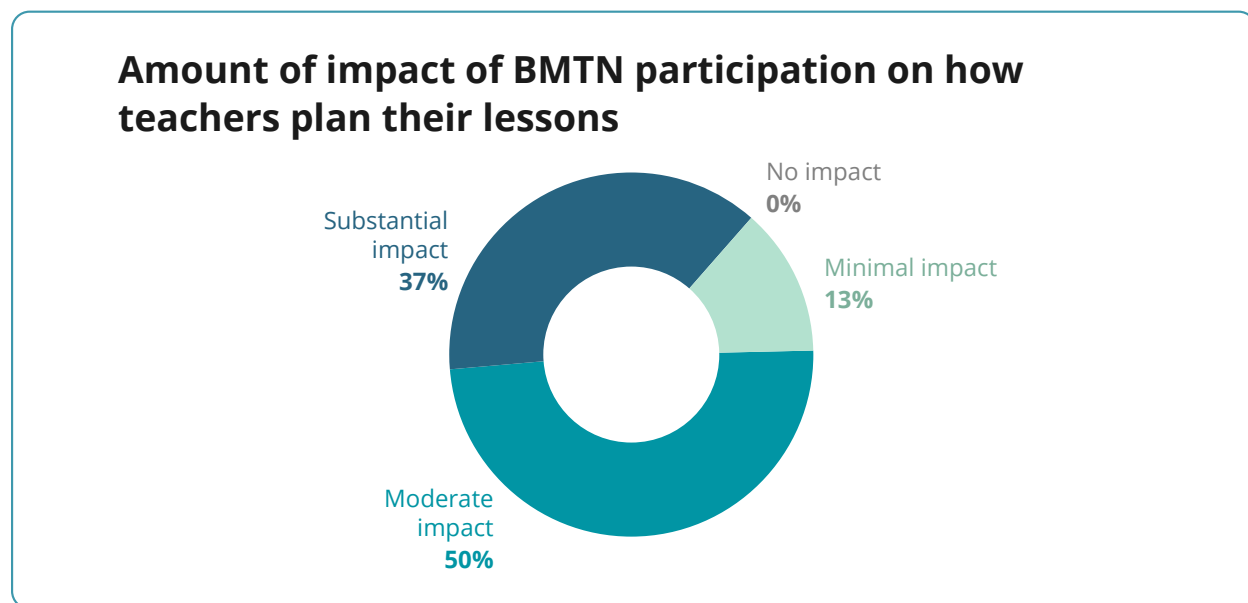
When we drill down to understand how the network has impacted planning, most teachers indicated that they used different tasks/activities, thought differently about how they would structure class, or both. See Figure 11. We also observe some cohort effects with more time in the network predicting a higher frequency of reported impact on how teachers structured class. Interestingly, the cohort effect does not hold for the selection of tasks, with fewer teachers from the earliest BMTN cohort reporting impact than their newer BMTN colleagues. This may be explained, in part, by the higher proportion of student-centered teachers in Cohort 1.

Figure 11: Proportion of teachers reporting changed practice by cohort

Change in practice as a result of BMTN participation
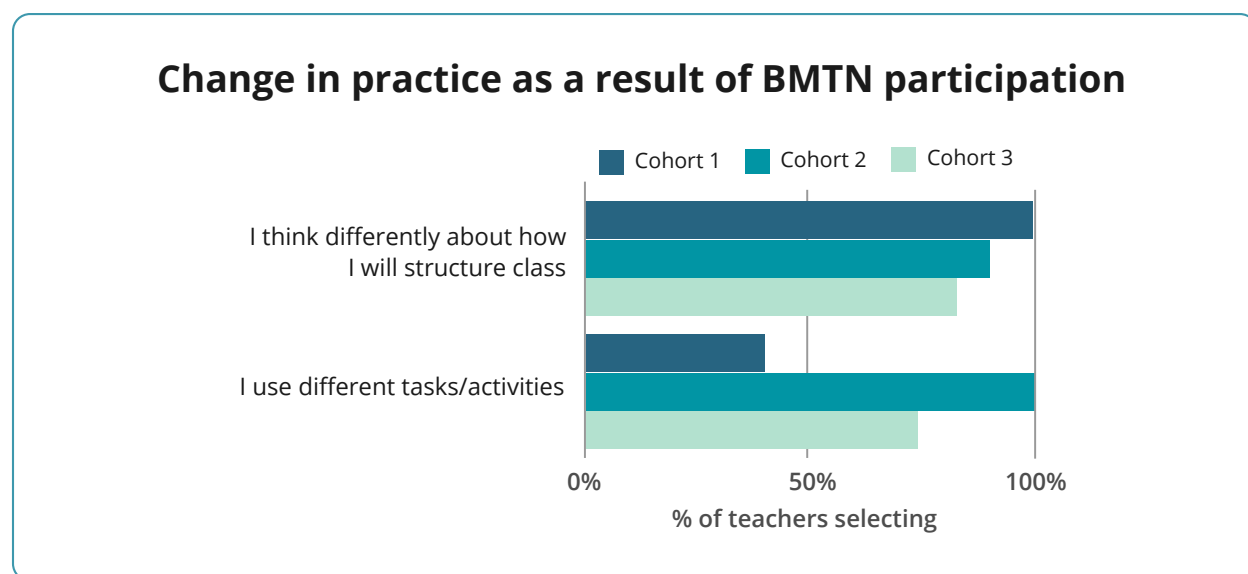
Teachers also indicated the magnitude of impact of network participation on their task selection. Figure 12 shows that more than half of teachers indicated a substantial impact with another nearly 40 percent indicating moderate impact.

Figure 12: Proportion of teachers reporting various levels of impact on teaching practices

Amount of impact BMTN has had on teacher practice

Legend: ■ Substantial impact ■ Moderate impact ■ Minimal impact ■ No impact

| Selecting tasks | 53% | 39% | 8% |
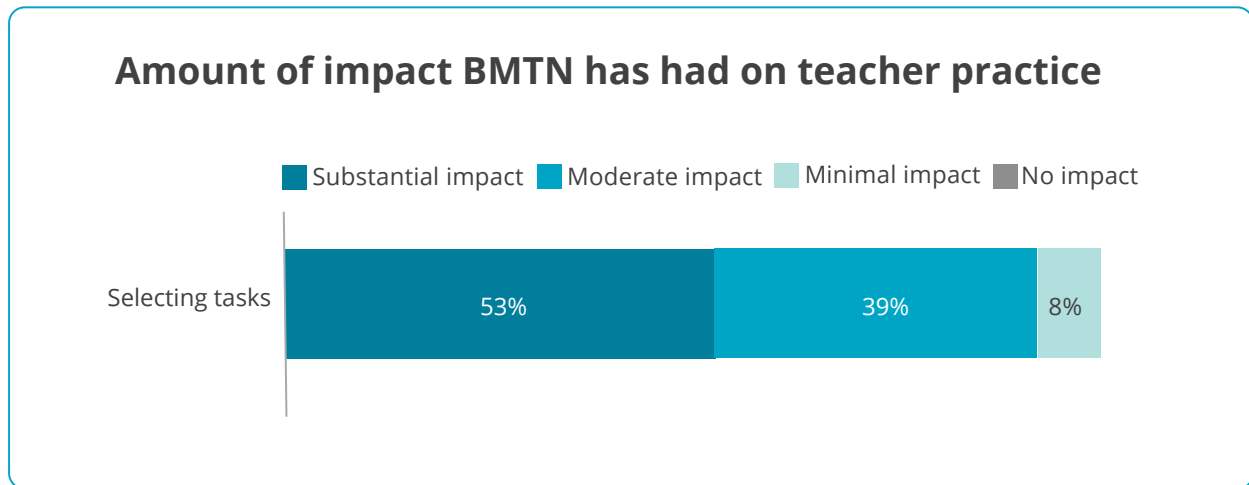
BMTN teachers agree that the learning task they use matters in terms of engaging their students. In fact, this is one of the key learnings that BMTN teachers identified during the summer 2018 convening when they reflected on what the network has learned collectively. Teacher insights about the task seem to be centered on both the relevance of the task and the extent to which the task focuses on conceptual understanding rather than skill development. The following vignette reflects how one BMTN teacher thinks about task selection in her work.

Vignette 3: Building the confidence to find and adapt high quality tasks

Angelina teaches at a full-inclusion school in an urban school district. Her classes include both typically developing students as well as those with mild to severe disabilities. She works with a special education teacher and, together, they co-teach about 23 students in each of their classes. About 80 percent of her students qualify for free or reduced-price lunch and almost all are students of color.

Angelina focused her BMTN work on justify. She wanted to support her students in making quality explanations for concepts in algebra, in part because her schools' state assessments had shown weakness in constructed response questions where students needed to explain their thinking and justify in words.

I got that idea from when we looked at our school-by-school data from last year. We noticed that many students did not score well on the constructed response on the state test. I think it was 30 percent of students actually got full credit on it, so we knew school-wide that this was an

instructional priority. We've been focused on writing across all content areas in my school for a while, and we were still unpacking state test data about how to improve this year. When we saw that it was constructed response, that's when I came up with it's not only the verbal justification, but it's now what students actually put on paper. I knew that there had to be some kind of protocol or some way to collect data within our PDSA on the quality of what students were writing, so that's where the justification in writing was born.

As she started to think about how to help students justify their mathematical ideas, rather than rely on an algorithm, Angelina sought more rigorous and relevant tasks and adapted these tasks to incorporate more writing about mathematical thinking.

The other reason that I wanted to work on writing was because I felt like when a kid is speaking, there's a little bit of anxiety around it. Yes, the talk protocols help to increase talk in my classroom, but I felt like if I give students an opportunity to think independently and write on their own, that would increase the quality of what they produce.

Angelina described using different tasks this year and using those tasks differently. She intentionally sought out a curriculum with tasks that provide meaningful context for students to justify their mathematical ideas in terms of relevant and accessible real-world applications. In addition, she adapted tasks to increase the opportunities for students to write about their thinking. She collaborated with two other network colleagues who work in her district to use an open-source math curriculum and work together to figure out how to adapt the curriculum for her purposes.

It's a school-wide priority to focus in on writing, which is why my PDSA's trials are trying to incorporate low levels of writing. I want to build students up to using a really rich task where they have to do their calculations and then explain what that means. More traditional tasks would probably start with, "This is a system. This is how you solve the system," without really providing students with a context, or having students work through that inquiry process.

It's definitely a shift that I've made because of the network, and it's in the amount of writing that they do. Before, if the problem called for writing something or providing an argument, we would do that, but I wouldn't plan for students to write any more than they needed to. But because of the network, I've been trying to incorporate more writing at low levels, just to build comfort with it. Because of the network, I've increased the amount of times I ask students to write.

Angelina now feels more confident in making adaptations to existing high-quality tasks to deepen students' opportunities to justify their thinking:

Now, when I look at a lesson, I can figure it out. I can look on my own, without having to talk to a bunch of people. I can think about, "What would be a good supplemental question to insert here that would first clarify understanding?" I didn't want the kids to be writing just to be writing. I wanted them to be writing about what we were doing, like something about the math, and that would help them clarify their thinking. In some way or shape, they're thinking.

In addition to more deliberate selection and adaptation of the tasks used, BMTN teachers also reported that they are more intentional about how they think about structured routines in their classroom.

> 66 *I have been more intentional about my selection and sequencing of tasks. In my planning, I intentionally use routines from our BMTN work in order to engage students in persistence during private reasoning time, discussion, justification, and the critique of their own and others' work.*
>
> *When planning, I had to make sure I was very intentional about the task I chose to be sure it led to being able to justify. I also had to be sure I would ask the right questions to probe student thinking."*

In reflecting on whether BMTN had an impact on their planning, some teachers described a shift from a focus on skills to a focus on conceptual understanding.

> 66 *I am choosing more robust tasks that elicit deeper connections and highlight important concepts rather than skills and have become more adept at talking about those important concepts and explicitly raising those connections with students."*

> 66 *I don't think I realized until I was taking the survey how much my planning has changed since joining the network. I am more thorough and think more critically about the tasks used but also have almost eliminated note taking in all of my classes. I'm more conscientious about engaging all of my students in the task that I want to give out. I'm thinking more about the big picture or concept I want the students to take away."*

Influence on student-centered practice

Teachers also perceive their engagement in BMTN had an influence on their instructional student-centered practice. With the exception of a few teachers who were very student centered when they joined BMTN, each teacher in BMTN indicated that engagement in the network has made their teaching more student centered. Figure 13 shows the distribution of how teachers reported their student centeredness when they entered the network and now. The distribution from pre- to post-participation has both shifted to a higher reported frequency of student-centered practice and the overall variability has decreased, both indicators of systematic influence of network participation.
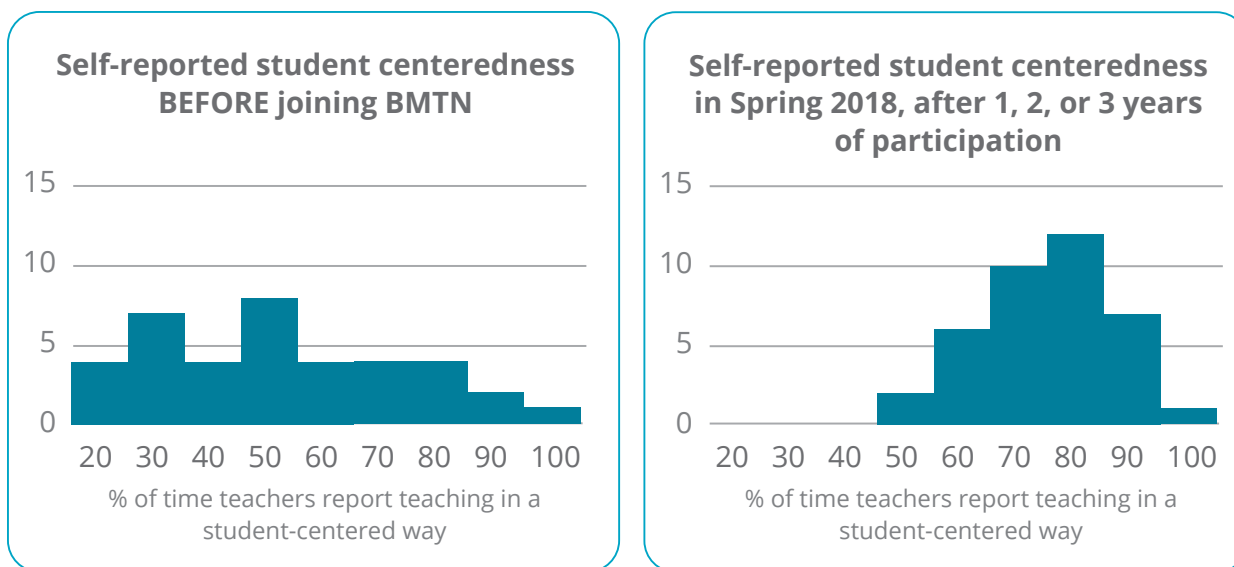
When we ask teachers to explain why their practice had become more student centered, nearly three-quarters of teachers attributed the shift to their participation in BMTN. See Figure 14.

Figure 14: Teacher attribution of student-centered practice change to BMTN
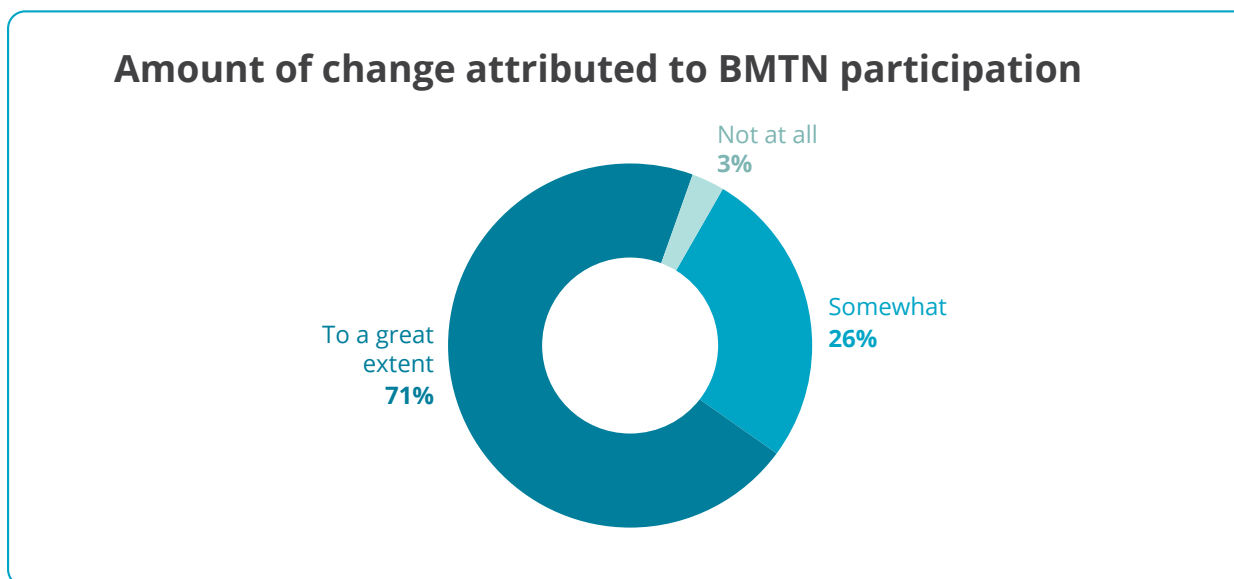
Not surprisingly, teachers who entered the network with higher ratings of student centeredness reported less change, since they began with a lower growth potential on that dimension. See Figure 15. The data shows that those who entered the network with moderate to high levels of student centeredness did not report much change while those who entered the network fairly low on this dimension had medium to high levels of change in their student-centeredness.

Figure 15: Array of teacher student-centeredness before network participation by amount of report change

Student-centeredness BEFORE joining BMTN	Amount of change in student-centeredness		
	Low	**Medium**	**High**
High	100%	0%	0%
Medium	81%	19%	0%
Low	13%	67%	27%

Many BMTN teachers reported an impact on student-centered math activities as a result of their engagement in the network. See Figure 16. We also measured the confidence teachers had in implementing these student-centered activities. Similar to some teacher reports on planning activities, some teachers report lower levels of impact on student-centered activities and high confidence, suggesting here, too, a possible ceiling effect.

Figure 16: Teacher-reported impact of network participation on using student-centered practices

BMTN impact on student-centered practices

Legend: Substantial impact | Moderate impact | Minimal impact | No impact

Practice	Substantial	Moderate	Minimal	No impact
Solving problems with a learning partner and getting help from each	39%	42%	13%	5%
Working individually and then sharing their thinking with a partner or small group	37%	45%	16%	3%
Thinking and reasoning about math	37%	55%	8%	
Working in small groups and/or with partners	34%	32%	29%	5%
Learning from each other	32%	53%	16%	
Writing reflections, justifications, and critiques	29%	45%	18%	8%
Sharing their thinking and problem solving with the whole class	26%	53%	21%	
Critiquing the work of others	21%	55%	24%	
Making mathematical discoveries	21%	47%	24%	8%

The largest share of teachers reporting substantial impact centered on practices that leverage peers to learn from one another in pairs and small groups. When we consider both moderate and substantial levels of impact, the largest share of teachers reported the following student-centered practices:

- Student opportunities for thinking and reasoning about math

- Students learning from each other

BMTN teachers who rated themselves low on student-centeredness when they entered the network reported greater network influence on their use of these student-centered practices than did colleagues who started off higher on student-centered practice. See Figure 17.

Figure 17: Relationship between teacher-reported pre-network student-centeredness and impact of network on use of student-centered practices

BMTN impact on use of student-centered math activities
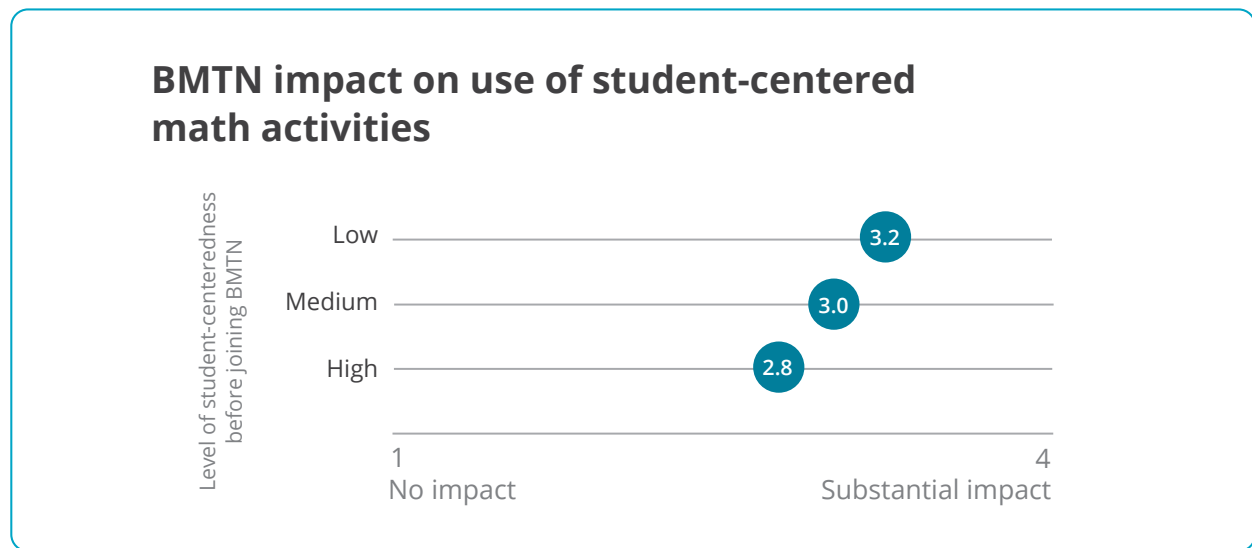
The following vignette reflects one teacher's shift to student-centered practice.

Vignette 4: Making ninth-grade math more student-centered

Aymee entered the Better Math Teaching Network a veteran teacher. Engaged in leadership roles throughout her district and state, she consistently looked for ways to improve her practice. Years ago, she shifted her instruction to be more student centered and was confident in her practices. However, when she transitioned to teaching ninth-graders, she found herself teaching in more traditional ways. She explained:

The big thing that caught me [about the BMTN] was the student centeredness. I had always been— past tense—had always been a teacher who facilitated a student-centered classroom. And then four years ago, my principal asked me to move from all my upper-level classes to take a freshman team. … I said okay. I got into the ninth grade, and all my student centeredness I threw out the window. It was a little traumatic because I found the level of maturity was not there. I couldn't do it with them because they wouldn't take it seriously. … They weren't motivated. You put kids in groups, and they're

going to talk about math instead of what's happening last night around 9:00? It didn't happen. So I threw it out. I was disappointed because the discovery wasn't there, and the investigations weren't there. They weren't owning their learning.

She described her former practice: "I would model. I would get up and I'd be at the front of the room, and I'd be exhausted by the end of class. The responsibility was on me all the time."

Aymee's engagement in The Better Math Teaching Network changed that. Seeing other teachers engaging ninth-graders in student-centered practice inspired Aymee to implement a classroom routine she had done prior to teaching ninth-graders. She described the routine:

A routine that is commonplace with every new task consists of:

- *3–5 minutes of quiet individual thinking time, where students are asked to reason about the stimulus and formulate a plan of action or prepare clarifying questions*

- *small group conversation about the stimulus: their first impressions, evidence of justification, components that are new, unfamiliar vocabulary, and*

- *finally, a whole group discussion, which is as brief or extended as warranted by students.*

As students became comfortable with the routine, I allowed them to control the natural segues. In this way, what was once a rigid and stiff routine has merely become how we learn.

Aymee built new tasks for her students to use as they engaged in this new routine. As a result of her BMTN work, she has a new approach to learning in her classroom:

The old saying "Learn by Example" is exactly what happens in my classroom. Using the routine explained above, students consider an exemplary example of a task they will be asked to perform. They engage in a task that aligns very closely to the work in the example. Students work individually and with each other in randomly assigned groups. The work ethic in the room is palpable. Progress can be slow on day one; however, students will give feedback using various closing protocols and adjustments will be made to support learning and success if and when warranted. Often, a well-designed example and exercise set results in widespread success on the second exposure.

Using inquiry cycles, Aymee has refined her routine and the way that she measures justification.

My quest for the year was to encourage deep engagement in the justification. In the end, I learned that I needed to be explicit about what justification looks like in its varied representations. I used a rubric composed of indicators from the original BMTN Justify Deeply Rubric and the [state] Graduation Competencies Rubrics. Structure was once a primary criterion for quality justification. In the midst of my fourth PDSA, analysis and the effective use of multi-representations to support a conclusion became the primary criteria for quality justification.

Aymee has found success this year in a variety of different ways. In her words,

- *This new routine requires everybody to engage. It holds them accountable to themselves. They know that if they're not engaging and they're not doing the work, then they're going to be clueless the next day.*

- *It has engaged students differently because I ask them to make sense of a concept through reading and thinking and in conversation with each other.*

- *I actually did a test that would be an Algebra II test. … They're solving production, sales, revenue, cost-profit situation. My whole idea was justified that these kids going through an in-depth analysis making connections to multi-representations. And the work they perform is unbelievable, unbelievable.*

- *I think the level of rigor [is there] because it's in application, it's real world application, it's conceptual understanding and it is procedural, all in one. So, the rigor is there every single day. Every single day the expectations are high.*

Structuring class differently

As teachers became more intentional about planning student-centered lessons, they structured their classrooms differently, changing the roles of both teachers and students.

Changing what students do in class

Many BMTN teachers report that they are increasing the frequency of activities in which students carry the "work" of the classroom. See Figure 18 below.

BMTN teacher report of student-related classroom activities

My students work in partner or small groups more often — **66%**

Students talk more in class — **63%**

My students have more independent think time — **53%**

We have whole class discussions more often — **42%**

% of teachers selecting
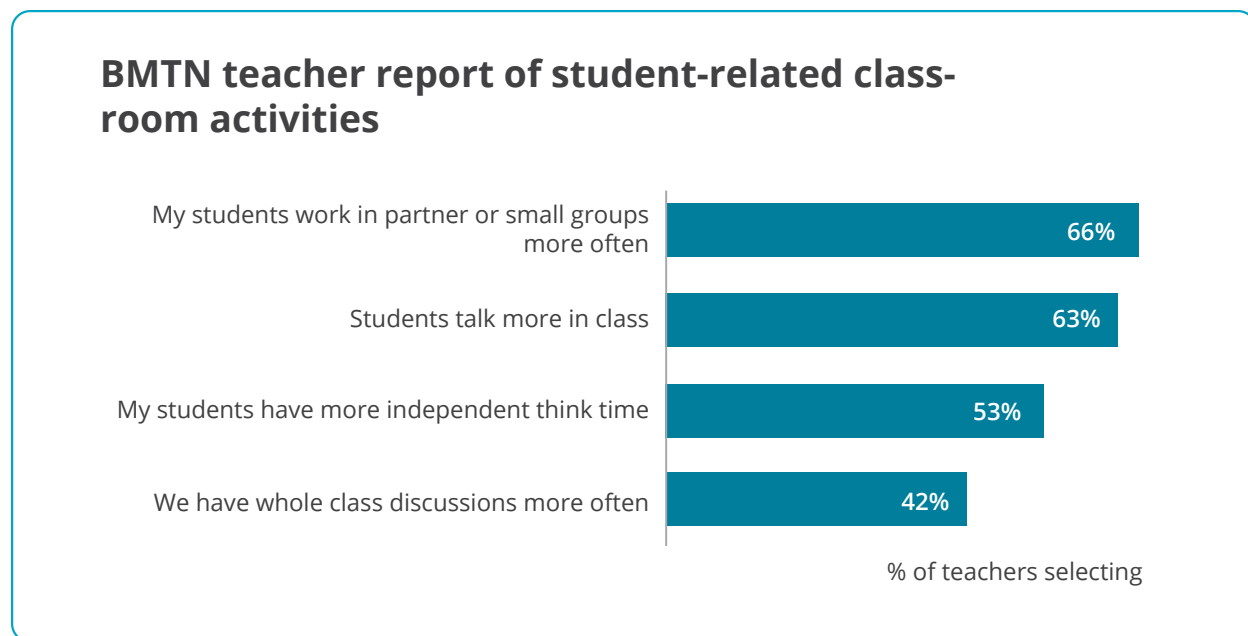
Changing what teachers do in class

In making these changes to have students carry more of the load in class, BMTN teachers also changed what they themselves do during instruction. Some BMTN teachers noted that they think differently about their role in the classroom. For example, some reflected on how they are now more aware of the questions they are asking students.

> *The hardest thing this year was coming up with the right kind of probing questions. I know what connection I want them to make, but how do I ask the question without making the connection for them? Right? And so that was really hard."*

They are more likely to give students time to work rather than "swooping in and telling them how to solve their problems." Figure 19 shows that up to half of BMTN teachers report changing their own behaviors during class time.

Change in teacher behaviors as a result of BMTN participation

I talk less in class	47%
I interact differently with students	37%

% of teachers selecting
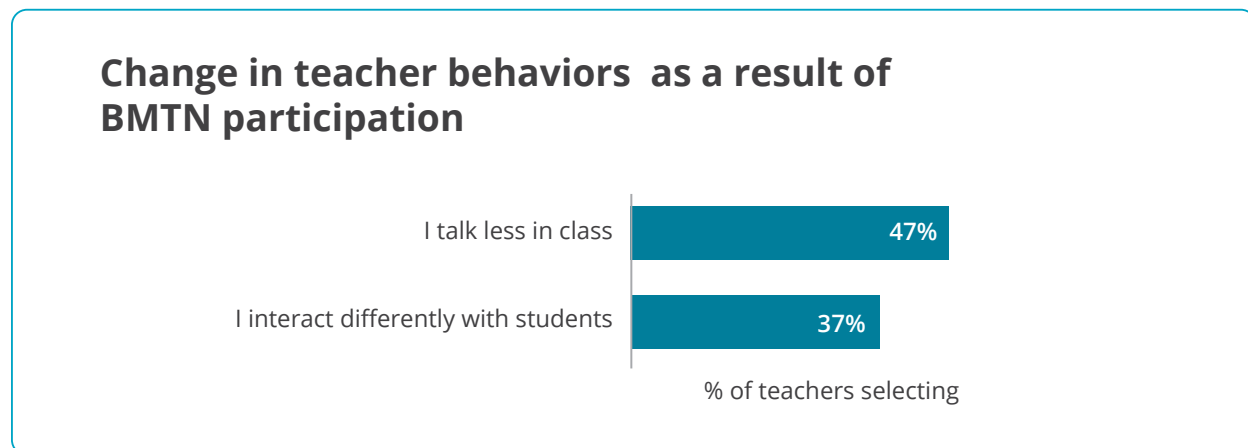
In the vignette below, one BMTN teacher reflects on how this shift worked for her in her first year in the network. She had always hung anchor charts on the walls of her classroom as a way to highlight for students the key learnings as they covered them. She changed this practice to be more student centered through her PDSA cycles focused on *Connect*.

Vignette 5: Who is doing the work in the classroom? One teacher's journey to help students make their own connections

Stephanie focused her BMTN work on *Connect*. She wanted to support her students in making deep connections in algebra.

> *Before my involvement with the network, I'd do a lot of guided notes with examples. Kids would diligently take the notes, and we would talk about them as we go. Hopefully the conversations would bring up connections, and I could explicitly show them the connection and how I thought about the connection.*

As she started to think about how to help students make their own connections rather than just listen to her make connections for them, Stephanie changed several things about her practice. She used different tasks, she engaged her students in class discussions, and she had students build anchor charts for themselves (and their peers in other classes) to use as references.

- Tasks: Stephanie described using different tasks this year and using tasks differently. She intentionally identified tasks that provided the opportunity for students to make connections to that task (or from that task to other things they had learned), and then take the time to make sure students were making the connections.

> *This year, I did a task, and it was much more student led. It always took longer. And then I had that prompt where I asked about connections instead of just the content. In the past, I may have said, "Here's a problem. Solve it using the shapes." I did that this year, but I also*

asked them, above and beyond that, "What's the connection between those shapes and a systems of equations problem that you would normally see?"

- Discussion:

  [Last year my discussions were] more teacher led, posing an open-ended question and waiting for student responses. I never had students respond to each other. In my head I was going to try to make that happen, but I never really got there. And I still think I'm working towards it.

  This was a shift for her, as well as for her students:

  It's hard for them not to watch me to see if they're right or wrong. They're so into, oh, no, I was right, or no, I was wrong. I think we're still working on that. Everybody. Me included. ... The questions I asked would have been open-ended questions around our content. This year it's definitely still open-ended around math content, but then making sure the connection is explicitly coming from students instead of me showing them the connection and saying, "Do you get it?"

- Student-designed anchor charts with connections:

  In the past, I would have only had the content-driven [anchor charts]. I would not have had ones that were trying to explicitly show connections between that intro task to what we were doing throughout the unit.

- Assessment: Toward the end of the year, Stephanie also started to think differently about assessment.

  I've changed this in my classroom and I'm collecting data for BMTN, but I'm not changing my assessments yet. It was too scary right now to change my big, end-of-the-unit assessment, so I wanted to see, if I captured these little blurbs [on their homework], what could I see from that?

  I would say that was a big change. Not only the task, not only how I ran the class, but also the things I was looking for as an end result of the task.

Her involvement in the network allowed Stephanie to try out new practices in her classroom as she sought to support her students in making connections in algebra.

The process that facilitated change

Engagement in the network has changed the ways in which teachers are planning and executing their lessons. It is also changing the ways that they think about their role, their students' role, and how they can facilitate learning in their classrooms. In this section we explore how their changes are connected to their engagement in the core work of BMTN—the inquiry cycles. Specifically, we consider how inquiry cycles change the ways that teachers use data, how change ideas are integrated into practice, and how teachers sustain change ideas over time.

PDSA cycles change how teachers use data

The use of data within the instructional planning, implementation, and subsequent planning cycle can be a powerful mechanism for supporting student learning, as instructional decisions are tethered to actual, rather than assumed, understanding. All the teachers who took the survey report that the network has had some impact on how they use data to inform instruction. See Figure 20.

Figure 20: Teacher-reported impact of BMTN on their use of data to inform instruction
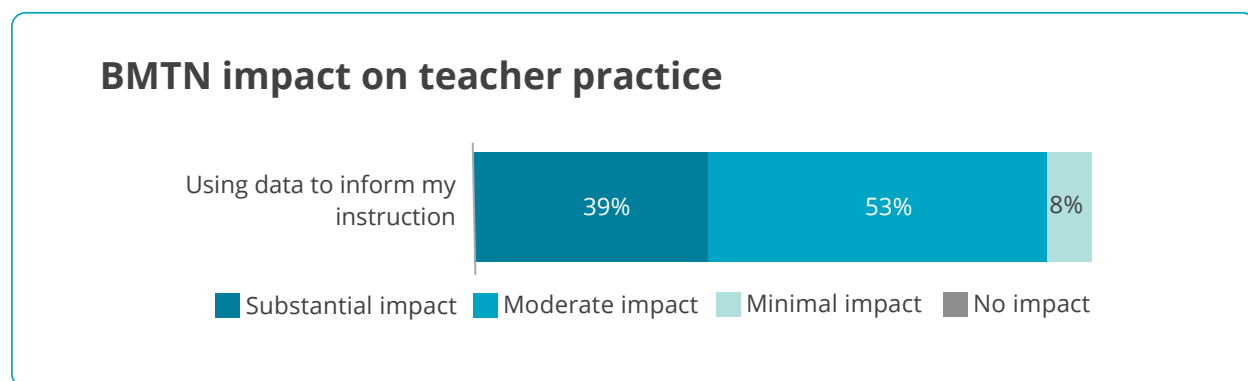
One teacher volunteered how integrating the use of data into her instructional decision-making was one of the most profound impacts of her participation in the network:

> *Before I joined the network, I wouldn't say I was very data driven. As a school, we take interim assessments every quarter, and we use that data to create a plan, how to reteach concepts, and then reassess to see if students learn the material in a different way. I think that I was nowhere near the data-driven teacher that I thought I was since I joined the network because I've become so much more reliant on collecting data and figuring out how that data impacts student learning. ... Now I'm using data to increase not only student achievement, but also student engagement, which has impacted my planning and my execution a great amount."*

Another teacher reflected on how she thinks differently about her use of data:

> 66 *I think that because I'm able to use a rubric to collect the data and to quantify or understand what qualities students are giving me, it helps me refine my data analysis skills. I think before, I was collecting data and making assumptions, and hypothesizing about why students struggled on some things. It's just an assessment, right? Now, I'm focusing on meaningful data, I'm focusing on the quality of the discussion, or the quality of a written response."*

Change ideas become integrated into practice

Half of the BMTN teachers reported that they tested their change ideas in more than one class in Year 2. See Table 1. This is an early indicator that the work may become a part of routine practice for some teachers. The difference in reporting by cohort suggests that this is something that happens once teachers have been in the network for longer than a year.

Table 1: Percent of teachers who test their change idea in more than one class

Cohort	Yes	No
Cohort 1	60%	40%
Cohort 2	60%	40%
Cohort 3	43%	57%
Total	50%	50%

Sustaining change ideas beyond testing cycles

Through the course of their engagement in the network, BMTN teachers try out different change ideas. We have evidence that despite moving on to new ideas in subsequent cycles, many of the teachers returning to the network for one or more years are still using change ideas from previous cycles within their routine practice. According to interview data, all 15 teachers in their second or third year of network participation who we interviewed continued to use change ideas from previous years. Ninety-three percent of those teachers said they were using at least a small piece of their past change ideas in their classrooms this year. Some reflected on ways they had adapted and adopted what they did as a routine and incorporated it as they set class norms or classroom culture.

> 66 *I would say I have implemented the basic routine that I tested last year, almost daily, in my class."*

> 66 *I definitely still use that student-structured math talk as a way to get them [to justify] quite often. I would say probably if not once a week, a couple times every two weeks, as a structure that's kind of become the norm. We then have students share out and make the anchor charts or make whatever it is that is going to become the public record. We keep those around the classroom, which was something that came out of the idea from last year."*

Many returning teachers said they are using parts of past change ideas and are still fine-tuning them, although they are no longer collecting data on efficacy. A few noted that they are not using previously tested routines because they might be teaching a different class or using a different curriculum. Overall, evidence suggests that BMTN teachers are, to a large degree, using practices from previous change ideas because they observed positive effects on student engagement or learning.

In this final vignette, we see how one urban teacher who has been in the network from the start uses the resources of the network—both people and material—to change her teaching practice.

Vignette 6: The road to more student-centered practice: Putting the pieces together

Anne works in a large urban high school that draws students from all over her city. Of the 900 students in her school, 63 percent qualify as economically disadvantaged, 53 percent are Latino/Latina, and 30 percent are African-American. School starts at 7:30 a.m., and because many of her students take public transportation to school—some with commutes over 90 minutes—many students arrive to school late. She teaches on a ninth-grade team that loops with students through tenth grade, and her BMTN colleague—who is also on her team—teaches in the classroom next door to hers.

In her three years as a network member, Anne has deeply changed her practice. The changes she has made have been largely influenced by her willingness to collaborate closely with colleagues in the network, her thoughtful use of the inquiry process, and her own willingness to take risks in her teaching. Anne's story is one that reflects the potential of NICs to influence the teaching practice of a teacher who is committed to continuous improvement.

Fertile soil

Anne was in her third year of teaching when she joined BMTN in 2015 as one of the network's pilot teachers. Her first two years of teaching were with Teach for America, after which she took a hiatus from teaching and completed a master's degree in educational policy. She wanted to go back to teaching, and she was energized to make changes to her practice.

> *I was in this new space where I was ready to try new ideas and ready to refine my practice. This was a transition for me. I was consciously saying to myself, I want to continue teaching because I want to be better, and my students deserve that.*

Setting the vision for student-centered teaching

During her first year in the network, Anne's understanding of student-centered learning deepened. In the network, the pilot teachers watched videos of student-centered classrooms and examined discovery-based tasks. As Anne engaged in this work, she began to think about how her practice might become more student centered. Another teacher in the network helped her. Anne reflected,

> I began asking myself, "What is student-centered teaching? What does that look like? What does that mean?" … Hearing about [BMTN teacher's] experience and the way that she designs her class really influenced me in the beginning.

A BMTN network leader (who was also her school-based math coach) pushed her to use more cognitively demanding tasks.

> It was the "new thing" and I wasn't clear what that meant or how to use them in my classroom. But the network really expanded on that. I think seeing examples from [BMTN teacher] of how tasks are actually used in the classroom, from someone who had that much more experience than I did—that really helped. Understanding what a student-centered classroom looked like gave me a tangible goal to work toward.

Anne noted that the first teacher whose work inspired her to think more carefully about student-centered practices taught in a very different context from hers. Anne sought out a second experienced teacher who worked in a context similar to hers to get more ideas and support. Anne's willingness to learn from others in the network helped her deepen her vision of student-centered teaching.

Learning her way to deeper engagement: Connect, Justify, and Solve

In her three years in the network, Anne engaged in PDSA cycles for each of the three DEAs (*Connect, Justify, Solve*). Her work in *Connect*, in her second year of the network, was her most productive. She reflected on how spending so much time on *Connect* allowed her to really refine what it meant to have students make connections.

> Previously I had always thought of making connections as making connections to a real-world scenario. I had not considered how to make deliberate and intentional connections to other math concepts. This expanded from, "How can I connect this concept or procedure to my students' lives?" to "How can I connect what we're learning to my students' lives and/or other mathematical ideas in order to build on their prior knowledge?"—whether it's prior knowledge from that same year or from middle or elementary school.

Her work in *Justify* was frustrating for her in the fall of her third year, mostly because she had planned her change idea around the students she had most recently taught (tenth-graders heading to eleventh grade whom she had looped with for two years) rather than the students she had (incoming ninth-graders). When her first PDSA cycle fell flat, she switched from *Justify* to *Solve*.

> I redid my process map and found I wanted to focus on "Solve" because my kids were really struggling with non-rote problems. I always heard them wondering, "I don't even know what this is asking. What is this asking?" They just kept saying that over and over again.

The work of some of her network colleagues helped her form her *Solve* change idea.

Hearing other people's ideas around solve helped me think about what it really means for students to engage deeply in problem solving. ... It boiled down to this idea that in life, you're always going to need to be able to use the information you're given and figure out how to use that information to solve whatever problem you are experiencing. This led me to focus on pushing my students to continually ask themselves, "What information are you given and how can you use it to solve the problem?"

That other network colleagues were grappling with the same challenge validated for Anne that this was a good focus. Here again we see how Anne sought to learn from others as she defined a line of inquiry that best supported her students' needs.

Shifting to more student-centered practice

The changes that Anne made happened over time, and in a variety of ways. First, she intentionally designed curriculum to facilitate connections. She rethought her role in the classroom on a daily basis and no longer filtered all of the information through her. "I started asking myself, 'What am I doing that the kids could be doing?' And pulling back on those things so that they are doing the heavy lifting, the thinking." She used the "I do, we do, you do" method less frequently.

She also changed the ways that she both supports students in her classroom and frames her lessons.

I began asking myself, "What knowledge do students already have that they can build upon to learn this concept on their own? What new knowledge do I need to help them build?" Now I think about facilitating their learning instead of delivering knowledge. I try to give them instructions that will guide them to understanding or discovery.

Finally, she structured her classroom space differently, clustering small groups of students together rather than putting them in rows that all faced her.

Social aspects of the work supported Anne in making change

Anne utilized the social aspects of BMTN to grow her practice. In addition to the two veteran teachers who helped her envision student-centered teaching in her first year, she worked closely with her school coach and one other BMTN colleague. She met daily with her BMTN school-based colleague to share work and co-create materials. In her second year in the network, her small PDSA group met in-person to collaborate outside of scheduled network meetings.

She found that meeting with teachers in the designed participation structures (e.g., whole-group network meetings, small-group PDSA meetings) built accountability into her work.

It's exciting because I get to see all these great math teachers who have become my friends, and we get to talk about our ideas. ... When you're surrounded by good teaching and good teachers you naturally want to elevate your own practice. The environment fosters a space to think creatively and try new ideas.

As a result of her engagement in BMTN, Anne now reflects on her teaching in a completely new way.

This work has changed the way I evaluate how the day went. Whether it's hard data, as in an assessment score, or looking at student work and grading it on a rubric or looking at how students were contributing to learning versus how I was—I reflect [through a] student-centered lens. And I think it actually allows for a lot more grace because it really is focused on the learning process.

When she finds herself frustrated because the lesson is taking longer than she wants it to, she is able to turn that around and see the positive things that are happening: "The kids were working for the vast majority of the class period. They were working together. They were using something they learned previously to understand something slightly new today, and I didn't feel like I was the keeper of knowledge in class."

Sharing an anecdote from her day, her pride in her practice is clear:

One student raised his hand and asked me a question. His group member—before I even answered—his group member said, "Why didn't you ask me that? I could have told you that!" Reflecting on that moment I thought, okay, they know that they're empowered to do this learning and share this knowledge together. And so even though it took a lot longer than I wanted or planned, they were doing the work and they were doing the learning.

Anne regularly sought out colleagues who could support her growth; she also was lucky enough to have BMTN colleagues in her building to work with for some of her years in the network. By engaging in change ideas that met her students' needs and bringing a willingness to continuously improve to the work, Anne significantly changed her teaching practice to be more student centered and to more deeply engage her students in mathematics thinking and discourse.

Implications

- Teachers' engagement in BMTN has influenced their practice. How can network leaders capitalize on the ways that teachers are changing their practice to articulate network learning, identify promising change ideas, and support the spread of promising changes?

- The influence network participation has on a teacher varies based on their needs and expertise. How can network leaders design differentiated supports to meet varying teacher needs?

Chapter 6: Teacher Perceptions of BMTN Impact on Student Engagement

The work of the Better Math Teaching Network (BMTN) is driven by the following problem statement: too many high school students are not meaningfully engaged in learning algebra, limiting their opportunities to succeed in school and career. As a network 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 ninth-, tenth-, or eleventh-grader still in Algebra I, you are more likely to be at risk." In an effort to solve this problem of practice, BMTN teachers focus on the aim statement: "to engage more students deeply in algebra by providing them opportunities to justify, connect, and solve with quality." These three areas of focus (*justify*, *connect*, and *solve*) are referred to as DEAs—deep engagement in algebra. By engaging in continuous improvement, through using tools and routines of improvement science, the network supports BMTN teachers to target all students in their improvement work.

The network's overarching design targets a diverse population of rural, urban, and suburban classrooms from across Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, and Connecticut. In Year 2, more urban schools in Massachusetts and Rhode Island were intentionally added, as those were underrepresented New England populations in the network's first year.

How many students might be impacted by BMTN?

In Year 2 of BMTN, the teacher participants had a combined 936 students within their target classes.[5] These target math classes included a range of courses, but the majority were focused on Algebra I. See Table 2.

Table 2: Math course identified by BMTN teachers in which they tested a change idea in Year 2

Target Math course	Number of teachers
Math 1/Integrated Math	5
Algebra I	26
Geometry	1
Honors/Accelerated Algebra 2	2
Algebra II	1
Unknown	6

Although many teachers did additional testing outside of their target classes and may have used learnings from their testing in other classes with other students that they taught, we focused our analyses and this chapter on teachers' perceptions of changes in student engagement in their target classes.

How are teachers conceptualizing student engagement?

We analyzed the documentation teachers produced at the end of their inquiry cycles—their change idea summaries[6] —to extract BMTN teachers' conceptualizations of *engagement*. In particular, we looked at the measures that they used to assess engagement within their PDSA cycles. Prompted by the distinction within the PDSA template, teachers generally offered their ideas for both *engagement* and *deep engagement*. Across all three DEAs, teachers generally conceptualized engagement along four dimensions, represented in Figure 21.

Figure 21: Teacher conceptualizations of engagement based on change idea summary documents

Teacher conceptualizations of engagement based on change idea summary documents

Participation	**Attitude**	**Effort**	**Attention**
Attempting a task or activity (tried it)	*Expressing openness to a task*	*Sticking to a task even if it is difficult*	*Actively listening and/or focusing on a task*

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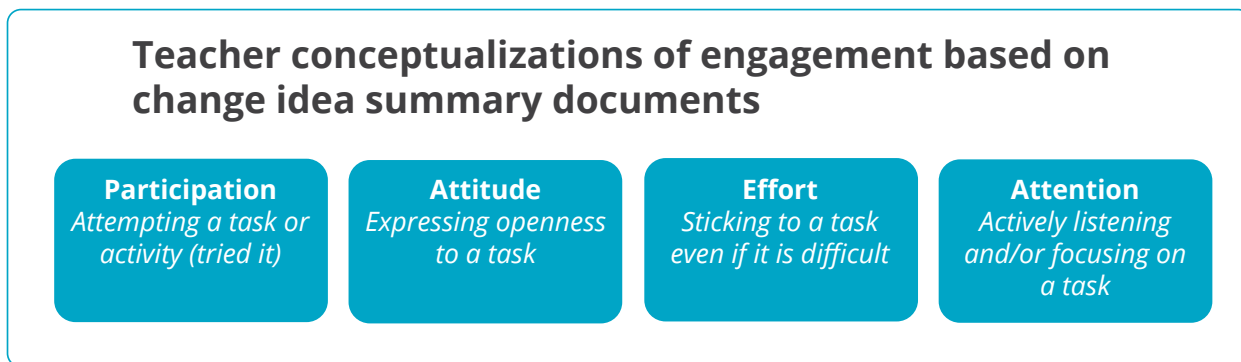
5   We refer to a target class as the class that a BMTN teacher tested out her change idea in a PDSA cycle.
6   The change idea summary is the documentation teachers crafted at the end of Year 2 to summarize their PDSA cycles.

To assess these categories of engagement, teachers overwhelmingly sought evidence of students attempting a problem or assignment, actually completing an assignment (regardless of accuracy), and talking or contributing to discussion. Outside of these three common indicators, individual teachers also looked for student behaviors such as enthusiasm, listening, staying on task, amount of time engaged in a task, amount of work completed, and communication of ideas.

In addition to *engagement*, teachers articulated how they conceptualized *deep engagement* and what they looked for as indicators of this concept. *Deep engagement* was conceptualized by teachers differently for each DEA as shown in Figure 22. We also included the number of teachers who submitted change summaries focused on each DEA.

Figure 22: Teacher conceptualizations of deep engagement by DEA

Teacher conceptualizations of deep engagement by DEA

Connect (N=5)	*Justify* (N=21)	*Solve* (N=8)
• Quality • Demonstrating understanding	• Explaining • Strategizing • Collaborating • Analyzing, synthesizing, & applying information	• Understand problem • Reasoning & strategy • Executing • Revising • Correctness • Restating • Confidence • Explaining
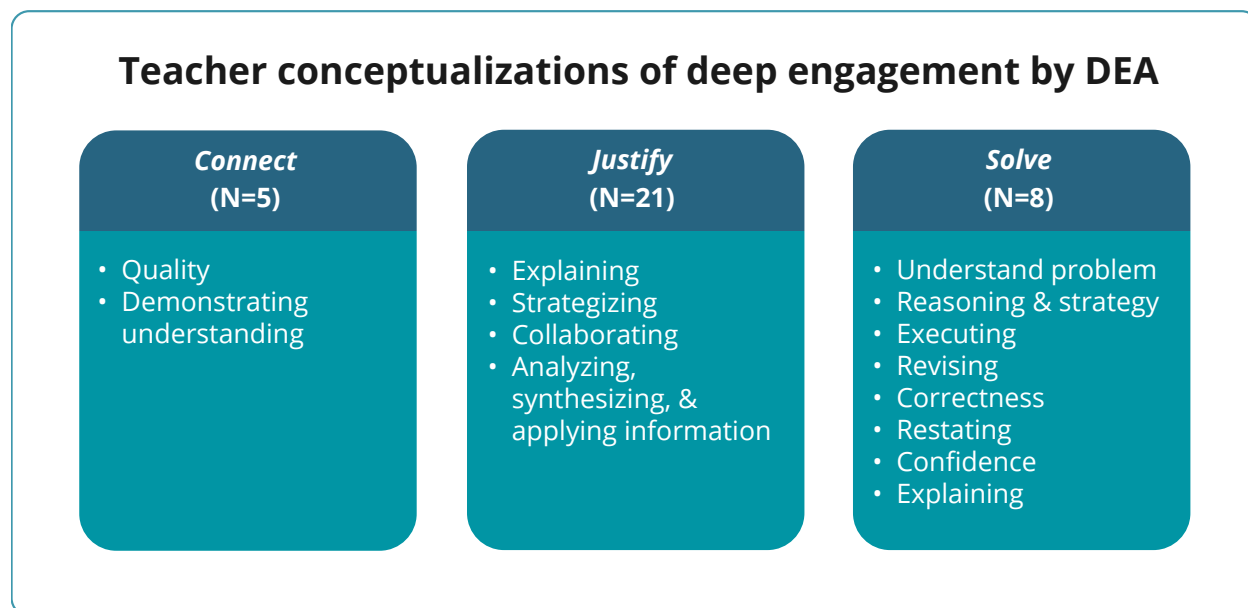
For the *Connect* and *Justify* DEAs, there was significant overlap in both conceptualization and indicators/tools used to measure across teachers, suggesting that some shared language and measures have emerged among subgroups within these two DEAs. For example, 60 percent of teachers within *Connect* used a set of indicators that included referencing the big idea or mathematical concept, correctness, employing logical reasoning, articulating a common attribute or structure, and making a clear argument. Within *Justify*, common language and shared tools were even more prevalent, as 76 percent of teachers who focused on *Justify* looked for students' use of mathematical concepts and relations, making a clear argument, and logical thinking as indicators of deep engagement with *Justify*.

How teachers conceptualized deep engagement and what they looked for to measure it for the *Solve* DEA was much more varied. The analysis showed an occasional similar conceptualization; for example, one teacher might say "understanding the problem" and another would say "identifying important details" which are similar in meaning. However, there was no core set of common descriptors for deep engagement in *Solve*. Despite a few instances of these overlaps, there was little evidence of shared language across teachers working in this DEA, and the list of how teachers thought about *Solve* was broad, including:

- Discussion
- Revising
- Making sense of solution
- Understanding the problem
- Important details
- Sensible approach
- Attempting, monitoring, and changing
- Reasoning
- Strategy

- Confidence
- Behavior
- Improve understanding
- Relevance
- Correctness
- Supported
- Explaining
- Restating
- Reflection on strategy and approach

Likewise, the indicators teachers working on *Solve* used to measure deep engagement were highly variable, with only one-quarter of teachers having any commonality. These common look-fors included students listing important information with reference, making sense of the task, and showing clear understanding in their own words. Outside of these, other indicators supplied by teachers included:

- confidence in ability
- follows group chat norms
- gives clear explanation with precise language
- shows conceptual understanding
- solutions supported by representations
- reflection on strategy and practice

Overall, teachers indicated that it took a lot of time and some "false starts" to figure out definitions for deep engagement through their PDSA work as they grappled with how to measure in ways that had meaning:

> **"** *I think my biggest challenge is to figure out, "How do you have a measure that's worth something, that tells you something?" You want to change your instruction based on data. Then, when you collect data, it's not all good. So, that was a struggle for me. What does deep engagement really look like?"*

For some, after this struggle, there was a sense of satisfaction with settling on measures that embodied conceptualization of quality that matter:

> **"** *I think [my measurement now is] better because what I was flitting about with before, my numbers kept coming up super high, but as a teacher you say, "I don't think they're working that hard and deeply engaged at trying to figure out why." My kids were deeply engaged at trying to solve something, because they like to be right, but I don't think they were working super hard and trying to figure out why things worked or why they were doing things. So, I do think I have something now that was working pretty well."*

Within DEAs, there was significant variation in how teachers are conceptualizing and measuring deep engagement. Within *Connect* and *Justify* there appeared to be some pockets of common language and indicators emerging, but this was not the case within *Solve*. This has implications for the network as they position themselves to arrive at and communicate promising solutions with a sufficient evidence base to warrant spread. Without a common conceptualization of what it looks like to *Solve* with quality, it will be hard for teachers to build on each other's work. In addition, how teachers conceptualize engagement helps us to understand their perceptions of the impact of the network on student engagement, which is explored in the remainder of this chapter.

In what ways do teachers perceive student engagement changing as a result of network participation?

We conceptualize the potential impact teachers' involvement in the network has on student engagement in four ways: engaging more students, engaging different students, engaging students differently within each DEA, and engaging for equity. We explore these potential impact areas by reporting teachers' assessments of the extent to which their network participation has resulted in a change in each.

Figure 23: Teacher assessment of impact of their work on engaging more students

90%

Moderate to substantial impact on engaging more students
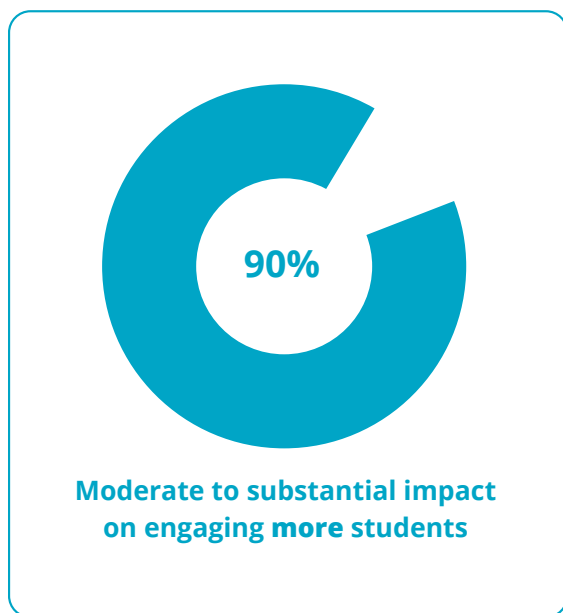
Engaging more and different students

When asked on the survey about how much of an impact participation in the network had on engaging more students, 45 percent of BMTN teachers indicated a substantial impact, another 45 percent indicated moderate impact, and only 10 percent indicated either minimal or no impact. Thus, teachers were quite positive about the extent to which they have been able to engage more students within their target class. There were no significant cohort differences. Teachers in urban contexts reported slightly lower levels of impact compared with those in non-urban environments, but these were very modest differences. This data point did not show change over time from the fall 2017 to spring 2018 surveys.

In talking with teachers about whether and in what ways they believed that their change ideas resulted in more students being engaged, about 77 percent communicated a firm belief that they were engaging more students. Another 20 percent thought that they had observed at least some progress but were hesitant to make a judgment because it is hard to measure and/or they did not have concrete data from before participation to after participation. Only one interviewee did not think that her change ideas had resulted in engaging more students and this was because she reported already having extremely high levels of engagement. She viewed her PDSA work as an opportunity to experiment with powerful ways to

engage students differently rather than engage more students. Most commonly, teachers indicated that their change ideas did result in "more students doing an assignment" or "more students attempting all parts of assignments and investing more time."

Several teachers said that the PDSA process spurs them to carefully observe student engagement which, for some teachers led to new insights about individual students and shaped the support they provide to engage more students in more powerful ways.

> " *I think going through many iterations allowed me to watch kids. Because I wasn't the one leading this, I could really see what they were doing and where kids were struggling, which gave me more opportunity to fix things so that more kids could feel like they were engaging.*"

Other teachers noted that the shift in student centeredness appears to have increased the frequency with which students share ideas during discussion, an important indicator of engagement for some BMTN teachers.

> " *Generally, when I give homework, we don't spend any time going over it. I don't think it's necessary. I don't necessarily have a good valid reason for giving homework other than just to practice some more and for them to do some of the work outside of class time. I just take it and say, "Yep, you did a great job." But this year I'm focused on the kids having conversations around it. They would actually come in and start talking about it before we had begun class. So, I would almost have to stop them and say, "Wait, we're going to have class time to do this so please hold off on your conversations." But they really wanted to talk about the facts and they were motivated by them. A few students told me that they preferred that style of homework, that they were being asked to use skills, but it wasn't a direct question like they were kind of used to getting for homework.*"

Interviews suggested that teachers believed their change ideas were helping less confident students have opportunity and voice to engage in the work. Typically, teachers spoke of these students as having less confidence, in part, because they had lower levels of math skills or math facts as illustrated by these two teachers:

> **“** *Even doing things like having a role was really nice because kids that are not as confident are never going to volunteer to be their table leader. But when I start to randomly assign these, they suddenly had that opportunity. I think sometimes kids just don't do things because they have never done it before. Then you get in this cycle of, "I guess I'm not that kid." So, mixing things up and kind of forcing them to move around and work with other people, I think just really upped the engagement."*

> **“** *I get engagement from kids that don't know their math facts right off the top of their head. I have more spirited debate on those days than I do normally. I also feel like kids refer back to those days more so than other days. It stays with them. I definitely feel like my kids that tend to get marginalized or don't talk when it's skill things, because they feel like math should be a simple answer and it should be a quick simple answer and they don't know their math facts. I get much more participation on my PDSA days than when I'm doing more skill-based activities."*

Engaging students differently

Teachers chose a DEA and then tested change ideas intended to engage students meaningfully in algebra concepts. To understand whether teachers believed that their efforts are indeed engaging students differently, we asked teachers to indicate the extent to which they believed that their change ideas have affected student engagement in connecting, justifying, and solving with quality. Figure 24 presents teachers' estimates of impact for the DEA on which they worked.

Figure 24: Teacher assessments of student engagement impact by focal DEA

Perceptions of impact on engaging students with quality aligned with teacher's DEA of focus

■ Substantial impact ■ Moderate impact ■ Minimal impact ■ No impact

Engaging students in *justify* with quality	57% / 39% / 4%
Engaging students in *connect* with quality	71% / 29%
Engaging students in *solve* with quality	25% / 75%

Quality is defined as depth.
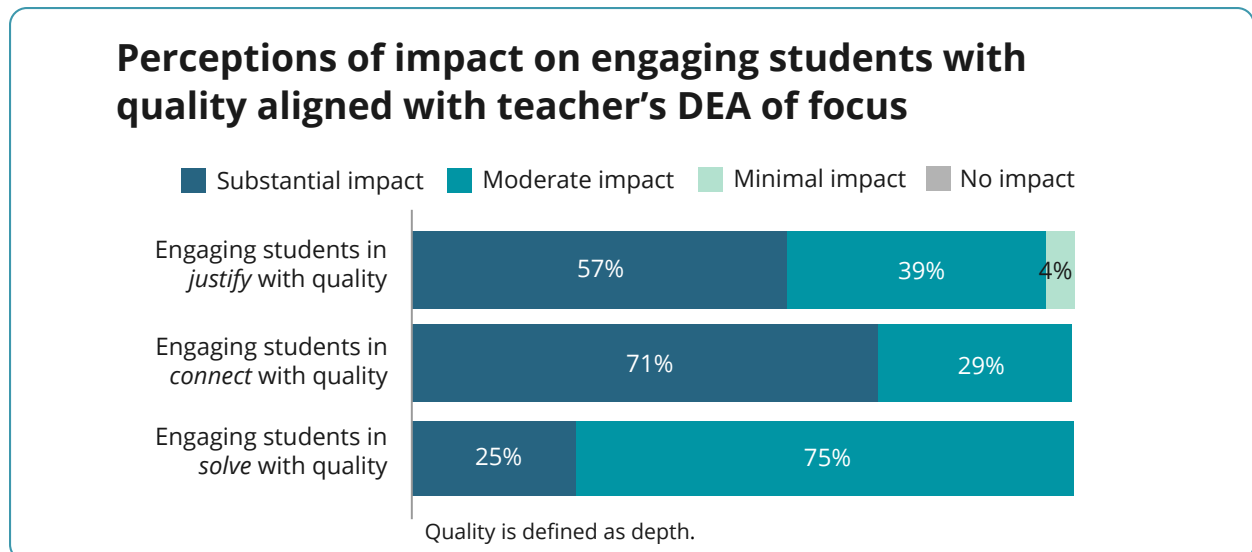
Interviews with teachers helped illuminate how they thought they were engaging students differently. Three key themes emerged:

- Students are more likely to collaborate to support math learning

- Student work now consists of writing and explaining rather than computation or rote learning

- The onus is more on students to do the thinking and really understand what they are doing

One of the most pervasive student engagement outcomes that teachers attributed to their change ideas was **students becoming much more collaborative**:

> *They go from private reasoning time to not asking the teacher but really just pulling in group members and sharing their ideas and thoughts. I think that that was more powerful than I thought it would be. I felt that they would just be saying, "Well, what I wrote was—" But instead they were bouncing ideas off of each other, and a lot of their original plans adjusted quite a bit through their talking with each other. A lot of students who had questions got their questions answered. I think that that was really powerful, it was more focused on other students, and collaborating, and joining ideas, rather than relying on the teacher as the only resource. I think that was a difference that I noticed that was really rich."*

> *I think my change idea was encouraging collaboration. In the past, I think that a lot of the practice that kids did in my class was more independent practice, kind of working almost in isolation. I had my desks in my room set up in rows and although they were allowed to talk, they kind of didn't talk to each other because they just were in their own workspace. So, my change idea had my room set up a different way this year. I had groups of three and four, in the way that the desks were set up. There was just a lot more collaboration and a lot more sharing of ideas and helping others and that was a big part of the idea and getting students to work together and to work differently."*

Teachers described offering more challenging and meaningful tasks to engage students, **increasing the extent to which students engage in writing and explaining mathematics** rather than computation or rote learning,

> *The intention of the project was actually to kind of veer away from doing several rote problems and just give them one good problem. And I told them I don't want you to spend hours on this. Spend 20 minutes and then move on with your life, get whatever you can down. Do some writing, ask some questions, even if you can't answer, that's okay. And one of the questions that I asked on the paper was how long did you spend on this? Because I wanted the kids to reflect that they were spending less time on it this way and then I would get kids who spent like 90 minutes on the assignments. So I had a lot of kids who really were engaged and wanted to figure them out and work them out themselves. I saw a big improvement in that throughout the trials that I did."*

> *My students had an easier time talking about what they were seeing. But I saw more engagement in the actual written explanation itself. You know, a lot of students just like to show you the math, and they don't really particularly enjoy explaining the math that they're doing. And I saw more of that, that explanation piece, especially in the written form."*

Teachers also described how the changes they have been making put the onus on students to do the thinking and really understand what they are doing; the students have a more active role and do more of the "heavy lifting":

> *I showed them three pieces of evidence, but I didn't tell them whether they were right or wrong. And so, they needed to figure out whether it was right or wrong, and I think that engaged them differently, because they weren't just solving."*

> *I think that they engaged them differently in the way that typically was justification, I think. It's usually, well, just explain your answer or just write about the math. And my change idea involved kind of building a justification. So like giving them the pieces of what would make a good justification… It made it more of a puzzle. It was just a kind of a different spin on how justification can look and how kids can get familiar with it before jumping all the way to [a full justification]."*

> *I think that having those routines in place has changed students' mindset about math and has made it more about looking for connections and patterns and ideas rather than it being about rules or procedures. Or when we are learning rules and procedures, they know that I'm going to always ask them like, "Why?" or "How?" or you know, "Where does that come from?" You know, "What allows us to do that?" So I think I did a little bit of that in my practice before this, but I think that having these routines and change ideas in place has flipped it so that's more of the focus of my classroom. And the content is certainly being learned and is important, but it's being accessed more and constructed more by students because of these routines that are in place."*

One teacher summarized that these different ways of engaging students shifted the classroom culture such that there is now space and structure for broad participation in mathematics discourse:

> *Suddenly, when you're trying to draw in and engage everybody, those people who love to over-dominate don't have all this free space anymore because, suddenly, other kids start to participate and they're throwing out their ideas. They didn't really know what to do with that. They're used to being able to be in a group, run the whole thing, do what they want. That threw them off."*

> *It really took me probably—I don't know—seven times of running this protocol that I have before they really went, "Oh, never mind; I'll wait my turn," without somebody else saying, "It's not your turn yet." I think that's really good for everybody. Nobody wants to be working in the group where somebody's trying to run it all. You don't really get to good stuff until everybody has a chance to be heard and to throw some ideas out there."*

Engaging for equity

To honor Nellie Mae Education Foundation's equity agenda, we explored whether there was evidence that teachers were engaging their historically marginalized students more. Overall, about three-quarters of all BMTN participants who teach those populations believed that participation has had moderate to significant effect on engaging historically marginalized students (including those with individual education plans, English language learners, students living in poverty, and students of color).

Since Nellie Mae is particularly interested in racial equity, the developmental evaluation sought to examine the work of BMTN through a lens that foregrounds race. Thus, we identified teachers who work with underrepresented minority populations and examined their perspectives on how the work is influencing their practice and their students. BMTN teachers who work in schools in which greater than 50 percent of the students are non-white and/or are eligible for free or reduced-price lunch (FRPL) were identified as teachers in high underrepresented minority (URM) contexts. Figure 25 shows that teachers working in contexts with high proportions of URM students were slightly more positive about the impact of BMTN work on their students' engagement than their BMTN colleagues who are not in such contexts.

Figure 25: Teacher perceptions of impact on students by URM context

Teachers with high URM populations report higher intensity levels of impact than teachers with lower URM populations

Legend: Substantial impact | Moderate impact | Minimal impact | No impact

URM: 43% | 43% | 7% | 7%
non-URM: 32% | 42% | 16% | 11%
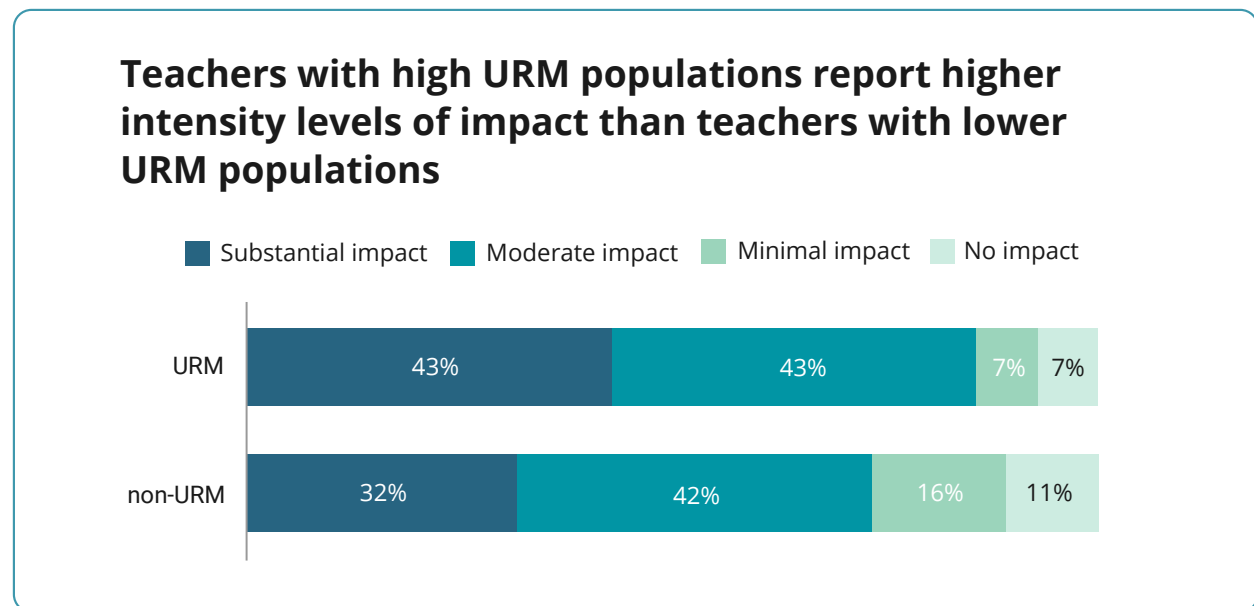
In interviews, teachers shared their views of how their participation in BMTN affected students from historically marginalized populations, including English language learners, those with individualized education plans, students of color, and students growing up in poverty. The key themes that emerged include:

- Change ideas that incorporate explaining and discussing appear to support English language learners and those who may be below grade level in math

- Moving away from rote problems with right/wrong answers to complex, conceptual tasks that are implemented with conversation and analysis supports academically low performers to engage

> " *I feel like I've been able to engage more of my [English language learners] since then, expressing themselves or writing it down. And I also know a part of that is in the culture that I build in my classroom.*"

> **"** I think it's helping students. For example, my students who speak Spanish tend to not contribute as much. My change idea was to have them talk to each other. When they talk to each other they help them find their voices in terms of math, right? I always say there's something about hearing yourself talk, hearing the sound of your own voice and I think that happened a lot more. Most of my students are students of color, low-income students, and I would say my change idea did help them speak about math more than they used too."

> **"** I think a big piece of that is rigor and not dumbing down the math for students …. To me, the best strategy to engage marginalized learners is to give them tasks that they deserve. You know, that the "smart" kids get. I don't know how to say it sort of smoothly, but if you're starting from a strong curriculum or a strong database of tasks, you know, that are well liked, that have deep conceptual understanding and then you're working on increasing engagement I think the real benefit is to marginalized students in the classroom."

> **"** I think 100 percent [of students] are free and reduced lunch at my school. Ninety-eight percent are students of color. So, I would say all of the BMTN work has had an impact because of the students that I serve. I do think that it has let me have those students think more deeply about the bigger ideas of math—and I think it's allowed me to become a better teacher for them, naming some of the skills that—those overarching ideas that are behind everything and helped me set a classroom where they're able to make the connections between things in a different way than before."

Despite these positive assessments of impact of BMTN participation on learning for URM students, a few teachers were hesitant to test their change ideas with classes serving many students from low-income or other marginalized groups that were struggling academically.

> ❝ *We have a lot of poverty here. They're not in this classroom. My students who have really grown up in poverty are in my Algebra I classroom. [That class is] geared towards the fourth grade. That's just where they are [academically]. It was a new class this year. [The school] made a cohort out of those groups, and I was a little afraid to do my testing there because when they gave them to me, their goal was just to keep them in school."*

This teacher's experience suggests that as the network continues to develop, network leaders might need to both encourage teachers to work with their classes that serve marginalized learners who are struggling academically and provide teachers with the supports necessary to ensure that the testing is helping these students.

To what extent is there evidence of network participation affecting student success?

Although the network's aim is focused squarely on increasing engagement rather than directly on student learning, we asked teachers whether they had any evidence that their students' learning had improved as a result of their PDSA work. Most of those who reported some impact on learning reported the following learning outcomes:

- Students' reading and writing in relation to math and math text/tasks has improved
- Students are developing conceptual understanding of mathematics principles

Teachers generally either did not have "hard" evidence of these learning impacts or suggested that they could probably compile the data from archived student work but did not have it readily available. Since the focus of the PDSA measurement is on engagement, only a few teachers had actually tracked any learning goals in relation to their PDSA.

One teacher had an interesting observation about how she shifted time to more student-centered experiences and saw similar test scores among these students as she had for previous students, making her question the value of how she had spent that time previously:

> 66 *My PDSA sometimes takes 45 minutes to an hour and I did it sometimes every 3 days. So, I find it very interesting that these students were able to get to the same end with all the regular curriculum kind of work and still miss that much instruction time. When you're thinking about direct instruction and me presenting stuff, you would think, "If I'm going to give up that much time on this problem-solving basis, that I wouldn't have still reached my end goal with my regular school curriculum." So, there something in this that tells me that they were able to learn better for themselves, maybe. Where's the data on that? I don't know. But to take away that much time from what I used to do kind of tells me that maybe what I used to do wasn't very important. But I think when they come in now, especially if they know it's going to be one of those days, they're really excited. So, I think when you get to a higher-level engagement and then you switch gears and do something else, I think they're just picking it up quicker. Because their test scores and everything when they came in were just average. They were no different than the kids that I had last year."*

Implications

- The data presented in this chapter rely on teacher perceptions of impact on student engagement rather than more objective measures of engagement. These findings suggest that BMTN teachers find value in the network for increasing engagement of their students in algebra. This is an important indicator of network sustainability and a potential predictor of increased student learning. In addition, network leaders have collected data from students to understand their perceptions of classroom practices around student-centered instruction, which also suggest that student engagement is improving (AIR: The Better Math Teaching Network: Lessons Learned from Year 2 Report).

- Data suggests lower levels of perceived impact for those working on the *Solve* DEA compared with *Connect* and *Justify*. Indeed, the work within *Solve* appears to be less coherent across network members than in the other two DEAs. Further efforts around network design and next year's research might further explore these differences.

- Teachers working in high URM contexts found the work to have moderate to substantial impact on their students' engagement, reflecting higher levels than their peers who do not work with similar student populations.

Chapter 7: Scaling the Network

As the Better Math Teaching Network continues to grow, design decisions made by network leaders evolve and shape participant experiences. In this chapter, we share insights about four key issues in scaling a networked improvement community as they relate to the growth of BMTN: meeting the needs of teachers at various stages of participation; maintaining a sense of connectedness within the community; negotiating the tension between quality of the experience and quantity of teachers in the network; and adapting the tools, routines, and roles for scaling.

Meeting the needs of teachers at various stages of network participation

Membership within BMTN is dynamic as a handful of teachers who participate in the work for one or two years leave while the network intentionally grows its membership by recruiting new teachers each year to join. At any point in time, the network is home to teachers who are veteran to the network and those who are new recruits, posing a design challenge for network leaders as member needs and levels of expertise vary. If these groups are to have their different needs met to engage in the network meaningfully, the network must be able to differentiate support in order to both scale and sustain the network.

As new members join a NIC, they are asked to learn on a variety of dimensions. This learning typically falls into three categories:

1. Social: What does it mean to engage in a community of professionals working towards a common aim?

2. Improvement science: What does it mean to engage in inquiry cycles, and how do I integrate that into my current practice?

3. Content: What is the new content that I am learning, and how do I integrate that into my current practice?

Our data suggest that new members were challenged most significantly by learning improvement science in their first year, followed by figuring out how to contribute to and leverage the resources of the network. Familiarity and practice are important; as members gain experience in the network, they become more comfortable with participation routines and improvement science methods. One teacher reflected at the end of her second year, "I think it's a very different experience your second year. You just know so much more about what you're doing." Another teacher shared a similar perspective, "I would say one of the biggest differences [between my first year and this year] is just my feeling of comfort. I felt very at ease knowing the system and what was expected of me."

This shift in comfort and confidence is particularly true in the area of improvement science. Since improvement science is a new methodology for almost all of the teachers who joined BMTN, learning this approach and integrating it into practice posed a challenge for nearly everyone. As BMTN enters its third year, our data clearly indicates that teachers new to this work initially struggled, but after a year of doing the work, they were much more confident engaging in inquiry cycles. "There was a huge learning curve last year. And this year [the PDSA cycles] felt like part of my practice. This is just what we do." Another teacher expanded on this shift,

> **66** *It made it so hard for me that first year to come up with a change idea, collect some information, make a decision, and either embrace it, tweak it, or move on. This year [second year of participation] was quite different. I feel like I was able to more swiftly move into and out of change ideas."*

This relationship between experience level in the network and confidence using the PDSA routine is also reflected in the survey data below, with the newest members (Cohort 3) reporting the lowest confidence levels. See Figure 26.

Average confidence level in using PDSA cycles to test change ideas by cohort

Cohort	Value
Cohort 1	3.80
Cohort 2	3.60
Cohort 3	3.09

1 — Not at all confident
4 — Very confident
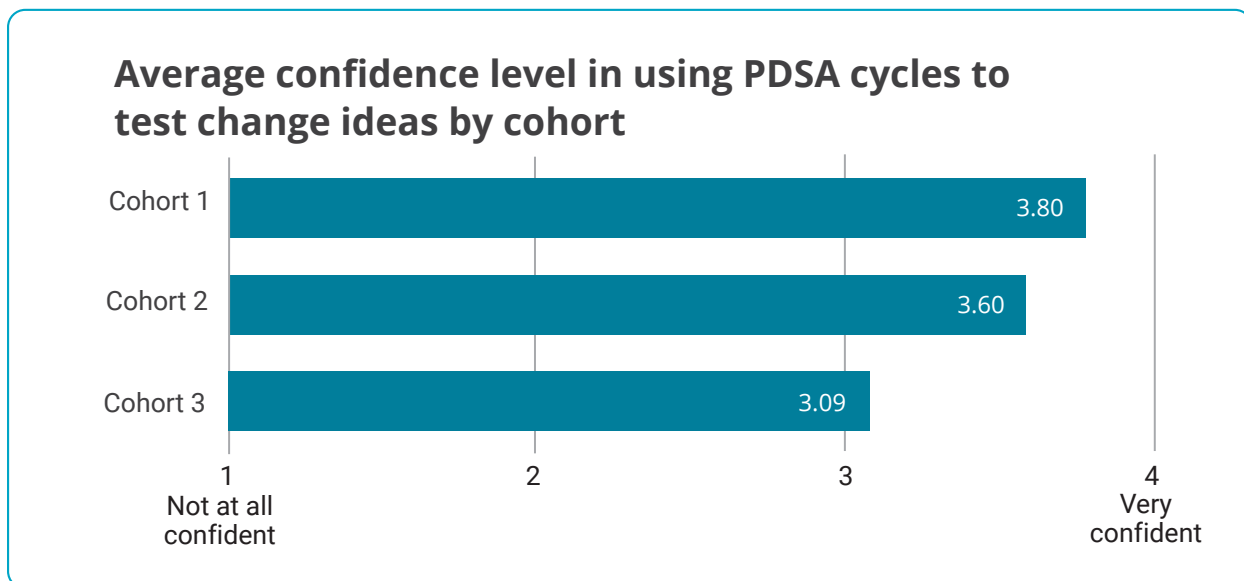
Teachers newer to the network and those who have participated for one or more years shared several challenges but also reported some that are unique. These differences are particularly important to attend to as the network scales; without supporting participant needs the network may not be able to sustain membership. See Figure 27.

Figure 27: New and returning teacher key challenges

New Teachers

Confidence in PDSA

Choosing the right "grain size"

Frequent early feedback on work

Knowing how to use the network

Time management

Having good measures

Returning Teachers

Professional goals misaligned with BMTN

Expertise to stretch their practice
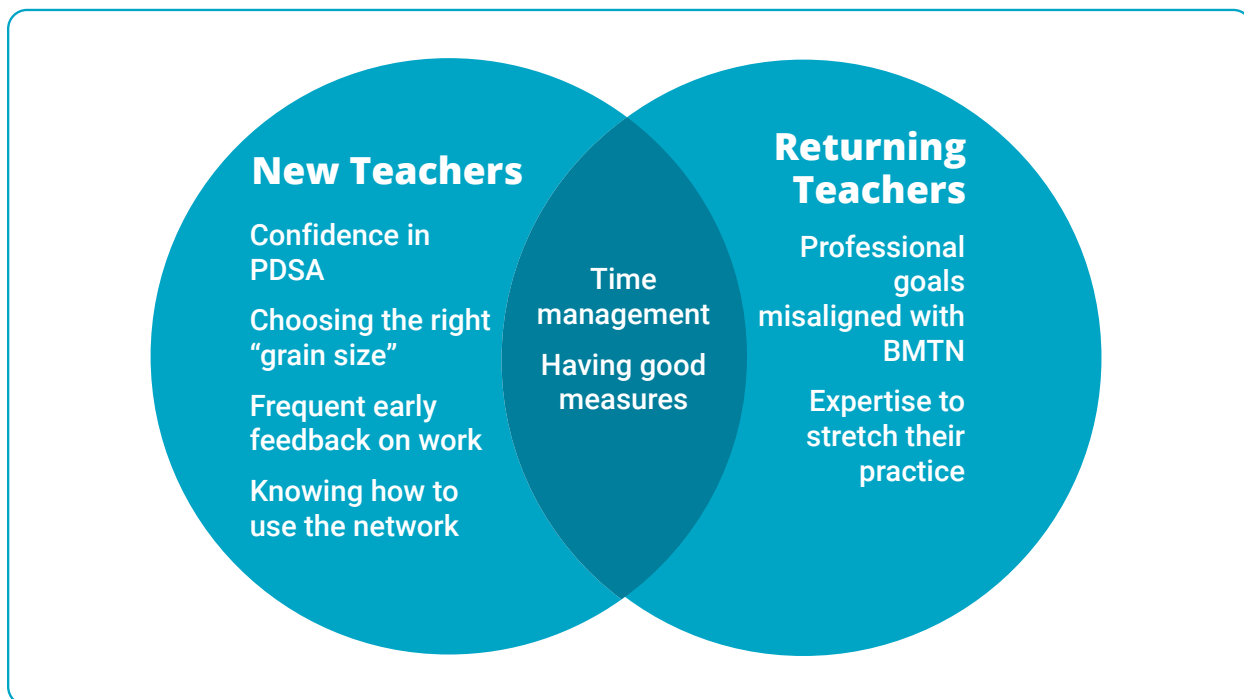
New teachers reported more challenges overall, and more of their challenges focused on transitioning into the work. Returning teachers mentioned more challenges having to do with the substance of the work, including lack of fit with what they want to work on and their need to interact with others who have expertise that could help them improve their practice.

Interestingly, both new and returning teachers reported the ongoing challenge of measurement. This issue is highlighted in *The Challenges of Improvement Science* chapter. In this chapter, we consider the scaling implications of this measurement challenge. While teachers in the first year of participation build comfort in the PDSA inquiry cycle approach to practice improvement, teachers in their second and third years of participation tended to struggle with how to identify, collect, and analyze data to know whether changes are an improvement. This is an area in which BMTN teachers were least confident. Figure 28 below shows low intensity of agreement across all cohorts, which indicates that the measurement challenges are present from the start and persist.

Figure 28: Teacher confidence in their PDSA measures by cohort

I am confident in the measures I am using to understand whether my change ideas are resulting in improvement

Cohort 1: 4.45
Cohort 2: 4.70
Cohort 3: 4.60

1 — Strongly disagree
6 — Strongly agree
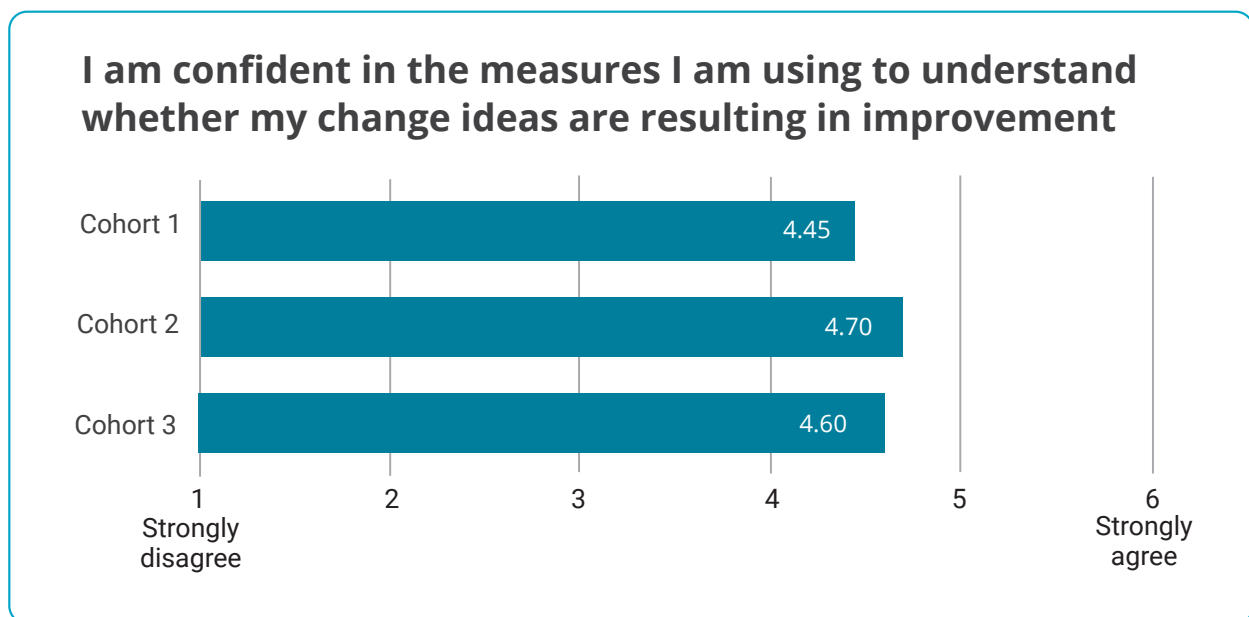
These differences are important to consider as the network scales and remains responsive to member needs. It is important for network leaders to consider questions like: How will the network support new members' learning about the PDSA cycles in a scaled model? How will teachers' use of practical measurement be supported as growth in membership is realized?

Maintaining a sense of connectedness

As the network grows its membership, there is a potential for the sense of connectedness within the community to be reduced. In particular, the number of people at the face-to-face meetings can reduce the sense of intimacy as this teacher observed:

> *I think the meeting felt a little different [this year] because there were just so darn many people. I think that I tried to not say as much during the meetings because everybody wants to comment on every little thing. It can be redundant, and it also gets us bogged down and you can't complete an agenda. In trying to be respectful of the agenda, I felt like I wasn't participating as much and that kind of left me thinking, "Well, did I stay too quiet?" You get into that dilemma of you don't want to monopolize, so that kind of left me a little confused on what I should be doing there."*

Some teachers reported changing their participation and engagement practices, partly in response to the size and structure of the meetings. Whole-group portions of the meetings became more challenging for participants to feel both active and productive. Participants also noted that the increased size made it harder to know what is being tested across the network.

> *I think the bigger we get, it's harder to talk to as many people who are doing different testing. So, for that stuff, I'll hear somebody talk about something that they are trying, and I'll go look in their PDSA [folder] so I can get ideas for things that are working or not. But it's harder to get all of that in a sitting when there are just so many people there."*

> *As the network is getting bigger, the NIC is almost too big for it to feel like a community. I can't keep track of what everyone's doing because there are too many people. When it was smaller, I knew what everyone was doing in their classrooms, and so it was easier to learn their story, hear how things were going, and be able to keep track of it along the way."*

As the network scales, a key challenge is for participants to be able to see the whole of the work of the network in a concise and digestible format. In this way, scaling a network puts greater demands on network leaders to consolidate what network members are learning and share that learning with the full network.

Survey data from the first two BMTN cohorts collected at two points in time (Fall 2017 and Spring 2018) suggest a small but meaningful decline in perceptions of opportunities to share with network leaders, with other teachers, and to learn about what other teachers are doing. See Figure 29.

Figure 29: Change in teachers' perceived opportunities to connect and share learning

Cohort 1 and 2 perceptions of opportunities to share and learn with other network members

● Fall 2017   ● Spring 2018

There are opportunities for me to share what I am learning about improving engagement in mathematics with Hub network leaders — 4.8 ● ● 5.06 —

I have adequate opportunities to learn about what other teachers are doing and/or learning — 4.07 ● ● 4.63 —

I have adequate opportunities to share what I am learning with other teachers — 4.27 ● ● 4.69 —

1
Strongly disagree

6
Strongly agree

These trends may have been influenced by the fact that the March network meeting was cancelled due to weather, suggesting that the face-to-face meetings are critical for maintaining a sense of connection in the learning.

Knowledge management

Knowledge management is an important function that NIC leaders carry out. In order to tap into the potential of the network to accelerate learning, network leaders must find ways to:

- harvest promising change ideas,

- assess whether the ideas are fruitful, and

- make the ideas available to others in a way that is easily accessible in order to test in varying contexts.

This is challenging and complex work, particularly in an instructionally focused NIC where teachers' change ideas can be context-dependent, tied to specific curricula, or narrowly focused in other ways. In addition, this work happens once NICs have been launched, trust has been built, and tools and routines are in place to support knowledge management. At the end of Year 2, BMTN is poised to begin this work. While network leaders have elevated some change ideas and pushed them out beyond the network (see *BMTN Spread: Building a District-Based Learning Community* chapter), they have not yet built the mechanisms for identifying or spreading ideas internally within the network, nor have they explicitly determined when and how to spread ideas (e.g., by defining when a change idea is worthy of testing by others).

As a result, when asked what the network is learning collectively, 79 percent of teachers interviewed were unsure. While they are highly excited by the work, and they can talk about what they themselves are learning, BMTN teachers are less sure about what the network is learning as a whole. Of those who are unsure, several of them believed that it would happen or that perhaps it was happening, but they did not yet know about it. In general, teachers focused their responses on the network's aim, defining the work of the network, and what teachers are learning.

Developing tools and routines for managing knowledge might mitigate these teacher concerns about not knowing what others in the network are testing as well as supporting ways in which teachers can identify the learning of other teachers that might be of use to their own learning.

Ensuring quality support as the network grows

As the network grows, direct support from network leaders must naturally shift, and, in effect, be reduced from previous levels of intensity (unless, of course, the leadership team grew in tandem with network membership). In Year 2, network leaders facilitated PDSA small groups in the beginning of the year. Network leaders did not attend the final meeting of the year; instead, teachers ran their own small PDSA groups with a leader-designed protocol. In Year 1, network leaders engaged in iterative revision work for PDSA change summaries but did not continue that practice into Year 2. Returning teachers felt these shifts:

> 66 *Part of the challenge was that I felt like we were a little bit more on our own this year. Because there were more people, we didn't have our small PDSA group meetings like we did previously. We would meet and talk and stuff like that, but we didn't have network leaders as part of [all of] those meetings, so that was a little difficult because there were times where we had questions, or we were just like, "Is this what we're looking for?"*

In particular, the role of the network leader as both an outsider and an expert during PDSA meetings was missed by many returners:

> 66 *[Network leaders] always give us a great perspective. It was still helpful [to have the meeting without them], but I would have really liked to have had them [in that last PDSA meeting]. Sometimes, if we're all having the same question, it takes somebody who's not deep in the work to remind you of what the goal was. I think that's the part that [the network leaders] always play for me. [The network leaders] are always like, "Yes, but we're talking about deep engagement here"—somebody to keep you on track because it's very easy to get off-track."*

As the network scales, network leaders cannot possibly continue to provide the same support to all participants. In year-end interviews, teachers indicated how they thought the first meetings went without a network leader. About half thought that the meetings went "well," 36 percent thought they went "ok," and about 14 percent thought they went poorly. We followed up by asking if teachers thought that running PDSA groups without network leadership was sustainable. About 28 percent thought it was a sustainable approach, 58 percent thought they could possibly be sustainable, and 14 percent thought they were not sustainable without network leader facilitation. Some teachers offered the following suggestions for sustaining these meetings:

- Early PDSA group meetings need expert facilitation to establish routines and culture.

- Groups should never be comprised entirely of new teachers.

- Someone else, perhaps a trained veteran teacher, could fill the facilitation role (which the network is currently implementing in Year 3).

> 66 *If it's going to be sustainable, then it can't just be on the network leaders. They have to look to others within the network to help. You know, other [network veterans]. People who can help with those meetings, who can be coaches, help with the whole-network planning ideas. Especially if there are going to be 16 more teachers next year. It's just pretty hard. And not sustainable."*

- Network leaders should provide clear ways for teachers to access their expertise and a structure for this access so that teachers do not perceive that they are asking for something "extra" from network leaders.

Some PDSA groups consisted only of two members; teachers in these groups noted that the conversation was limited without the network leader to facilitate the final meeting. Almost half of BMTN teachers (47 percent) viewed meeting with their PDSA groups as only "moderately useful" or only "a little useful," and thus did not have the ongoing, meaningful network support during the year that network leaders intended.

Overall, the reduced supports in Year 2 were described by half of the returners interviewed (53 percent) as a reduction in collaboration:

> 66 *I felt like there was a lot less collaboration, a lot less people who were working in groups. I felt like everybody was doing their own individual work this year. And while that's great, I just find it frustrating because you are limited by your own brain and your own ideas. My first idea was terrible, and it wasn't until I had conversations with other people that my project actually shifted into something that I wanted it to be. All of a sudden it became what I thought was a great project. ... I wish there was a way to get more of us working together so that we're not just trying to think of these ideas off the top of our head and then be some kind of revolutionary. Because if I already had the idea, would I already be doing it?"*

Adapting tools, routines, and roles for scaling

As the network grows, it is adapting the tools, routines, and roles to respond to participant needs in a more generative and sustainable way. Given what we have learned about variations in participant needs based on experience levels, shifts in the sense of connectedness, and the challenge of maintaining quality supports as the network grows, we offer a few considerations for ongoing design and implementation work:

- **Institutionalized mechanisms for transitioning new members**
  Network leaders are building a case exemplar that provides a detailed example of planning and implementing a PDSA cycle. This can be made available virtually to all new members. Network leaders also, wherever logistically possible, put new members into PDSA groups with returning members. *What other aspects of the work can be codified and institutionalized?*

- **Scaling access to expertise and rigor**
  Network leaders have played a critical role in teachers' learning and engagement with PDSA cycles. *How will expertise, rigor, and perspective be available within the network and to whom?*

- **Scaling quality controls**
  We know that the participation structures (e.g., network meetings, PDSA meetings) are the critical components for engaging members in the work of the network. As network leaders pull back from their direct roles in some of these structures, *how might quality of interactions and work still be monitored and shaped?* For example, PDSA groups are

an important space to build knowledge and support for the deep and in-between meeting work that teachers do, but we know that not all of these groups end up with active and productive engagement. Without a network leader at the table, some of these groups may actually dissolve. *How might network leaders measure and monitor the relative health of PDSA groups and intervene as necessary to shape the quality of the work?*

- **Differentiating work and roles**
  It is clear that new and veteran network members have different needs and assets. *What models will network leaders employ to integrate new and veteran network members and ensure that the work of the network can be conducted with more members?* In Year 3, network leaders have designed new leadership roles for veteran teachers. *What are we learning about how the shifting roles do and do not meet the needs of all network members?*

- **Managing knowledge**
  As the network grows, so too does the volume of work produced by its members. This creates a new challenge for members and the network overall: it becomes more difficult for network members to have a clear, conceptual understanding of the various strands of work and learnings that are emerging from individual teachers' PDSAs. *How might network leaders capture, curate, and disseminate promising change ideas, tasks, measurement tools, and other useful resources, and make them accessible to network members? How might network leaders create a coherent representation of what has been learned so far about the network aim?*

Implications:

- As networks expand their membership, the needs of members change. This requires network leaders to continuously tweak the design of supports to new and returning members, which might include restructuring participation structures, constructing new tools and resources to showcase the learning and manage new learning, and differentiating member experiences.

- Returning members in a growing network can be assets to the new members, but also must have their changing needs met. How might the network be designed to ensure that returning teachers have access to the expertise that will stretch their practice and understandings?

Chapter 8: Spread in Year 2

A networked improvement community is a network of practitioners and researchers who collectively work on an important problem of practice. These networks measure success by tracking progress toward a common aim and use improvement science methods to learn how to improve practice. One promising feature of an instructionally focused NIC is that the field of education can potentially benefit from the NIC's identification of promising instructional practices in order to accelerate improvement in other schools and classrooms. This chapter examines the different ways in which the Better Math Teaching Network worked to spread its impact in Year 2.

Informal spread

Naturally, teachers in the network have been excited to share what they are learning with colleagues. There are a number of informal mechanisms BMTN teachers are using to spread their learning to colleagues in their schools. In Year 2, 84 percent of BMTN teachers surveyed reported that they shared their work with colleagues outside of the network. The majority shared individually with other math teachers at their school, but some shared at their school more broadly. See Figure 30 below.

Informal mechanisms used to spread BMTN to local colleagues

Another math teacher(s) in my school	88%
In a math department meeting	59%
Another non-math teacher(s) in my school	41%
In a faculty meeting	13%
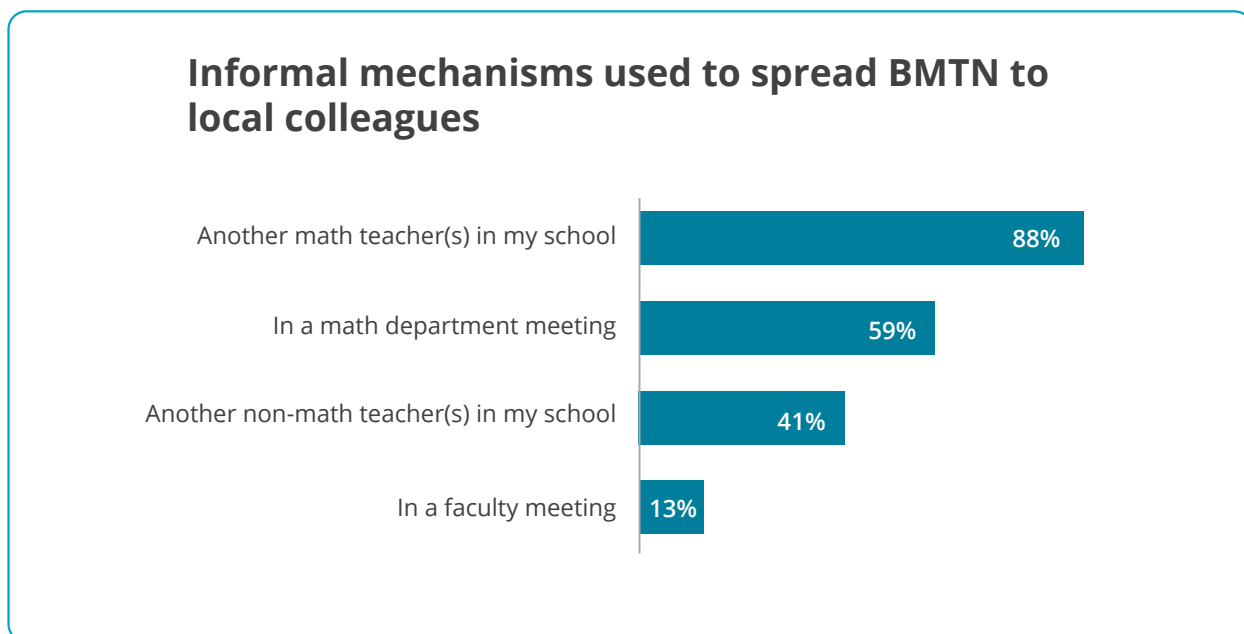
A few BMTN teachers shared with educators beyond their school context. When asked what they shared, most BMTN teachers who shared beyond the network focused on sharing math-related elements, but slightly more than half of the teachers who shared have spread the improvement science approach. See Figure 31 below.

Figure 31: Proportion of teachers reporting the content of what they shared beyond the network

What teachers are sharing with local colleagues

Math ideas (n=28)	88%
Math routines (n=26)	81%
Math tasks (n=25)	78%
Improvement science process (n=17)	53%
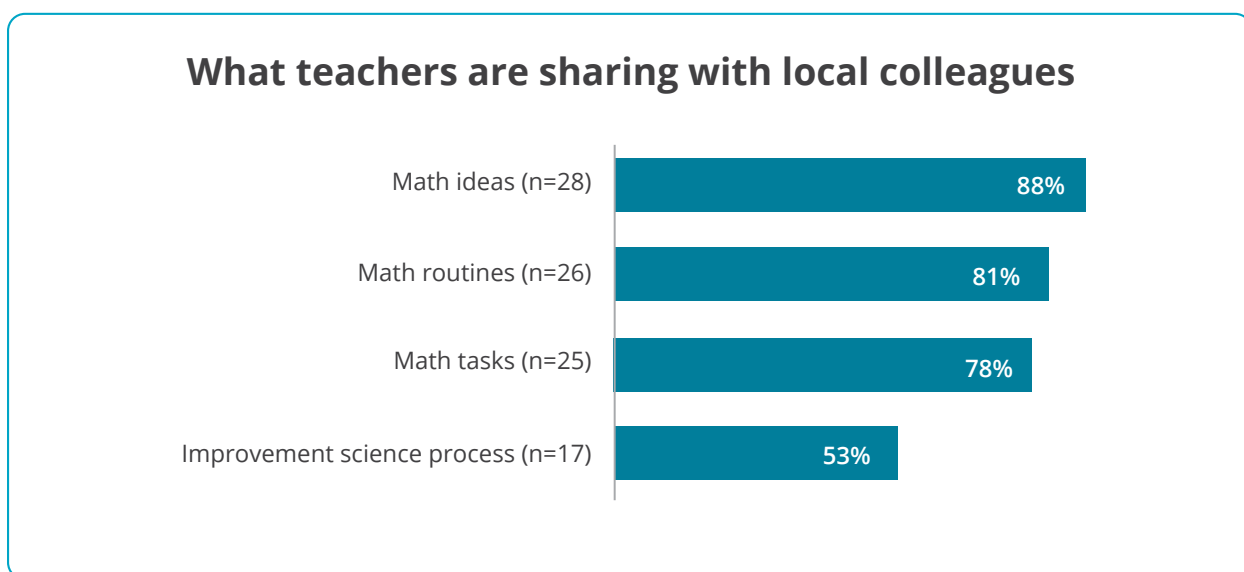
In interviews, teachers described ways in which they shared their BMTN work with colleagues outside of the network:

> 66 *When we discuss instruction [at my school], I am focused on student-centered aspects. In addition, I encourage teachers to try out a small idea and collect data, then decide if they want to keep it or refine it."*

> 66 *I have offered strategies that I used in the classroom that worked for me or my BTMN colleagues. As a department, we have collaboratively used ideas that I found worked. I also have a colleague in BTMN, and we have collaborated on some change ideas for success in our classrooms."*

> 66 *I encourage [my school colleagues] to try my change ideas that have been successful or other ideas that I am using that I have learned from my network colleagues."*

The following vignette describes how a teacher who joined the network in the pilot year took ideas from the pilot year and used them in a context beyond the network.

Vignette 7: Integrating continuous improvement into practice

Brianna is an experienced teacher who joined the network as a pilot teacher in 2015. She was already quite student centered in her practice and was involved in other professional learning opportunities as she sought new ways to learn with and teach others in her urban district. In her third year of the work with BMTN, Brianna was ready to push her learning beyond her classroom and the network.

Brianna considered the PDSA cycles to be a good tool for improving practice. She also appreciated the collaborative nature of her small group in the pilot year, when a few teachers tested out the same change idea, collected data, and reported back to each other. She wanted to bring inquiry cycles and this idea of joint work into another project in which she was engaged. Brianna simplified the PDSA template and, with another BMTN colleague, used it to guide improvement work in a new context. She explained, "We were doing a similar data inquiry cycle around testing instructional techniques in the classroom, and we actually used a more simplified version of the PDSA form."

Her simplified form had the following elements:

- A description of the change idea

- A Plan

- Three questions under "What do you want to learn?"

    · Will students engage?

    · Will students engage with depth?

    · Will I do it as frequently as planned?

- A "Do" section: Describe what happened

- Study and Act

By maintaining key elements of the inquiry process, but shortening the template, Brianna sought to simplify the effort required of teachers for documentation. Since she did not find the prediction step in the BMTN PDSA cycle to be useful, she left that out of her revision.

She shared it with two colleagues in the same district, both of whom were seasoned teachers and had engaged in inquiry-based work prior to their collaboration. Brianna described how they used the form for work testing out feedback they gave to students:

We all filled out our data in the same sheet. We were testing a feedback idea, giving students feedback. It was really neat to actually see the different classes. One teacher is a special education literacy specialist with third-graders, one teacher is a seventh-grade math teacher, and then [BMTN colleague] and I both teach Algebra I. It was really powerful to see a strategy work across classrooms.

Brianna went on to describe that while there was variation across their four classrooms, the form allowed for themes to emerge that were easy to analyze. Reflecting on this work, Brianna shared,

I like trying the same change idea with other teachers. … I think you get more data. I think that a theme in your classroom might resonate with another teacher, or you both might find the same thing. For example, we were testing this idea of matching feedback to student work, and we all noted high engagement among students. Students really liked the technique, and that's something that I might be able to say about my own classroom for my idea, but I think when we see it as a more universal practice, it can be more beneficial.

When Brianna reflected back on this work within the BMTN context, she shared:

One of the things we are trying to do in the network is come up with strategies that people can take to scale. I think when you have a bunch of teachers working on the same idea, you're getting better data to support that idea. I think trying the same idea in a range of classrooms just adds more support to whatever the change idea is, if it works.

In Year 3, network leaders are more formally supporting BMTN teachers to share their BMTN work with their school or district colleagues. Several teachers have signed up to share in a variety of ways that include professional development sessions for district math teachers, school-based opportunities for math teams or—in some cases—for all content area teachers. BMTN teachers planned to teach their local colleagues about new math routines, inquiry cycles, and/or student-centered teaching.

Formal spread

In the first two years, BMTN network leaders designed four mechanisms for the network to spread its impact, which we examine below.

- Creating a public face of the network via Facebook, a website, and a monthly newsletter.

- Encouraging BMTN teachers to present to the broader math education community via conference presentations and blogs.

- Establishing a parallel network of school, district, and state math leaders.

- Establishing a learning community of new teachers to test out BMTN change ideas.

See Figure 32.

Figure 32: Different ways in which BMTN leaders design for spread in Year 2
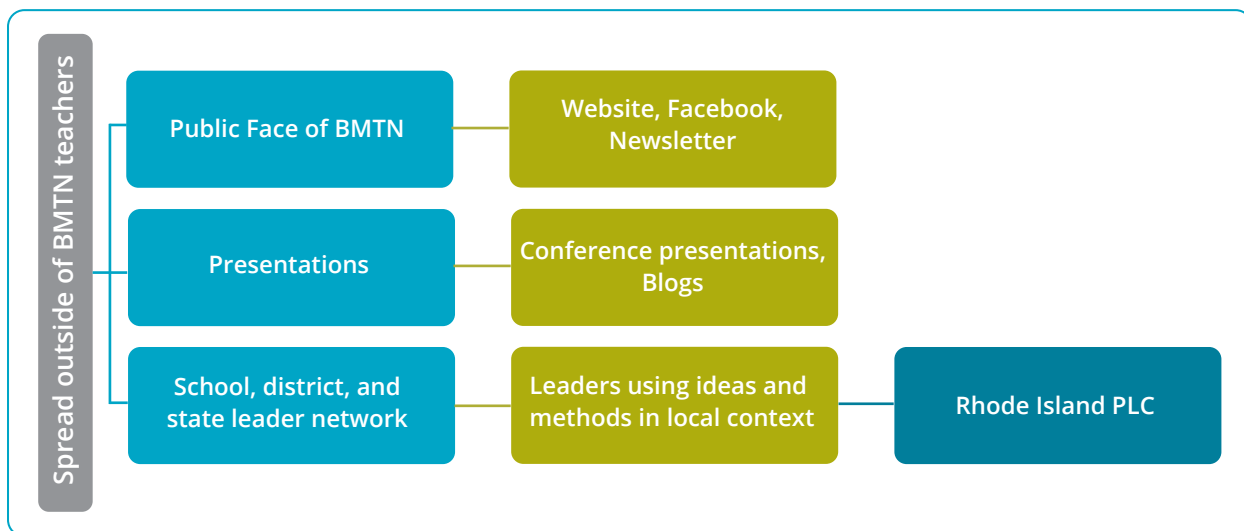
The public face of BMTN

Starting in Year 1 and building in Year 2, the network's communications team built the public face of the network in three venues:

1. **Website.** The network launched its website early in the network's development. Over time, network leaders added content to the site. In addition to sharing information about the network, the website serves as a repository of BMTN member-generated ideas for change.

2. **Facebook page.** The network launched a Facebook page early in the network's development. This is a place where anyone can go to learn more about the network and where teachers can link ideas, invite others to conferences, and connect in other ways.

3. **Monthly newsletter.** In October 2017, the BMTN hub launched the first monthly BMTN newsletter. Sent to all members, and anyone who has subscribed on the website (currently 150 subscribers and counting), this newsletter shares member profiles, news of upcoming events and articles of interest, and news of the network.

BMTN member presentations and blogs

The Hub encouraged BMTN teachers to present at local and national conferences and to write blogs. Ten teachers (25 percent) presented or will present at conferences and one teacher has blogged about her work in BMTN. Teachers have presented at the National Council of Teachers of Mathematics Conference as well as at state and regional conferences. They have presented on a wide range of topics including how they use improvement science to improve instruction, how they have developed and implemented new routines in the classroom, and how they define deep engagement in algebra. Additionally, some members presented on the work within their schools or districts.

Leader network

In the pilot year of the Better Math Teaching Network, 11 teachers were joined by three district and state leaders who engaged side-by-side with the teachers in the network meetings and then—to varying degrees—took the ideas back to their local contexts. One of these leaders moved into a Hub role when the network launched the following year. In the first full year of implementation (Year 1), network leaders continued to work with school, district, and state leaders, but in a different model. They held two virtual meetings to keep leaders in the loop and bring new leaders into the work. Leaders were invited to the year-end full-network meeting to hear what BMTN teachers were sharing and to celebrate BMTN teachers' learning.

In Year 2, network leaders again designed a parallel meeting structure for the leader group comprised of two in-person meetings in fall and late winter.

- September 2017: Five district leaders and three school leaders attended the kick-off meeting. Two state leaders were interested, but unable to attend. Participants learned more about the Better Math Teaching Network, improvement science methodology, and some of the change ideas that BMTN teachers were trying in their classrooms. Network leaders asked leaders to try out a BMTN teacher's change idea in their own context.

- December 2017: Two state leaders, one district leader, and two school leaders met to continue their learning, share their experiences from trying out the BMTN change idea with teachers in their local context, and plan for future work.

Network leaders refocused the leadership work after the second meeting. They sought to build professional learning communities in local contexts as a way to spread the improvement science approach and continue to try out BMTN teachers' change ideas in new contexts. A state and school leader showed interest in continuing the work in this way, so a network leader partnered with them to grow the work in their local context. See *BMTN Spread: Building a District-Based Learning Community*. Members of the network leader group were also invited to the end of year BMTN network meeting in which teachers shared their learning from the year. Two state leaders attended this meeting. The other six leaders did not continue with BMTN.

The continuous improvement element of the BMTN strongly resonated with several of the school, district, and state leaders, particularly with those who engaged more deeply in the pilot year. There is evidence that some leaders have integrated BMTN ideas into their own work and/or to support the learning, growth, and improvement work of others they lead.

> 66 *A district I'm working with needed a way to think about how they are going to identify how they want to change, and how they want to pick data. Some of the tools [from BMTN] were a good segue into that work—they were a good way to talk through that."*

> 66 *I brought the whole concept of the driver diagram in articulating your goals and picking one thing to focus on to my work here at the [state] department—pushing us as a team to think about: what are the things we need to accomplish? Which is going to give us our biggest bang for the buck?"*

> 66 *The teachers who are going to become math coaches go through this training, but we also have assigned field coaches from the university that go out and observe them in their teaching and provide actionable feedback and see how they are working as a coach. We've used this work to think about: What kind of feedback? How is your interaction with the teacher you're coaching? What strategies do you need to improve on? We are using that cycle with our field coaches to support the coaching candidates with the classroom teachers that they are working with. I've kind of woven it into a lot of things I do."*

Some leaders also appreciated the wide view of high school math teaching it provided for them and the challenges with which teachers were grappling.

> **"** *I have an opportunity to hear from teachers across the New England states about what they are trying, what's working, what's not working. It gives me insight into areas of need for professional learning so that when I think about my next steps at state level, what am I going to provide for support sent to teachers out in the field?"*

Some of the state, district, and school leaders had ideas about how the network might further use their expertise. For example, one leader suggested that participating leaders might:

- build a database of resources and supports for teachers to access so they are not spending time looking for good materials.

- provide training around research-based strategies to support teachers in their PDSA work. *"What does that strategy look like or feel like as a student?" And then flip it around and say, "What are the teacher moves behind that?" so that the students have that value-added experience with that routine or strategy that the teachers are trying to implement in their change process.*

Building a Learning Community

In February of Year 2, BMTN network leaders launched a learning community at a New England high school. The math department chair of this high school, who had attended the meetings for state, district, and school leaders, was excited to bring the ideas from BMTN to her school. Network leaders worked closely with her to design a model that worked within the time and resources they had available, co-constructing the model with her to fit her interests. The learning community was designed to:

1. Spread change ideas and continue to test these change ideas

2. Spread improvement science methods

3. Pilot the use of PLCs to spread the work

Eventually, network leaders may support these groups to identify and test their own change ideas. If successful, this learning community could serve as a model that BMTN teachers might take back to their schools and districts.

The district-level learning community that was piloted in one state in Year 2 engaged math teachers from that district's one high school and both of its feeder middle schools. This was the first time that most of the teachers had the chance to collaborate with district colleagues and to learn math-specific content together. Teachers were universally happy to be given a routine to try out in their classroom and a rubric to assess student work. All of the teachers tried out the routines in their classrooms. There were varying degrees of data collection, analysis, and documentation completed. Much of the conversation focused on challenges with students (e.g., it was new for many of the teachers to engage their students in non-rote

tasks so there was a learning curve for both them and their students), challenges with finding good tasks, and building coherence between middle school and high school math in the district. (Please see the case write-up in Chapter 9 for a fuller explication.)

Implications

- There are a variety of ways in which ideas and new learning from NICs can spread beyond network members. Network leaders must intentionally design and manage these mechanisms, which in turn will focus both the ideas that are shared (e.g., improvement science strategies, classroom routines) and the audience for whom they are intended.

- An important job of network leaders is to consolidate learning, package it into deliverable components, and test out successful strategies for spread.

Chapter 9: BMTN Spread: Building a District-Based Learning Community

Mary Lou had been the head of the math department at a high school in New England for nine years. When she learned about the Better Math Teaching Network, she was very interested because she immediately saw how the network could support her goals.

> 66 *I wanted to join the network because I was looking for some national help or support for my school. I have a high failure rate in Algebra I. I have managed to decrease that over the years—it was high when I started—but that was one of my biggest concerns as a department chair: How do I reduce the Algebra I failure rate in my school?"*

Along with a math leader from her state department of education's office, Mary Lou attended two meetings in late 2017 to learn more about BMTN. In these meetings, AIR-based hub leaders met with school, district, and state math leaders not affiliated with BMTN to share ideas from the teachers' work and support the spread of those ideas beyond the network teachers. In the first meeting of the leader network, Mary Lou learned more about what the teachers in BMTN were doing, received an improvement science tutorial, and was given a classroom routine to bring back to her school that had been created

by a BMTN teacher: *Inserting Non-Rote Problems into Instruction*. As she and her colleagues tried out the routine, they found it to be useful in engaging more students.

Mary Lou and her state leader were interested in integrating BMTN's work in their local contexts as they sought ways to improve math teaching and learning. Mary Lou was particularly eager to engage her algebra teachers in the process of improvement cycles. Since her district is small, and there is no district math coordinator, Mary Lou often looks for ways to support math learning across the district. When the leader network met again in December, Mary Lou was ready to push the work more deeply into her local context. After that meeting an AIR-based hub leader, Gail, collaborated with Mary Lou to build a math learning community in Mary Lou's district. Mary Lou invited the math teachers from her high school's two feeder middle schools to join the work as well.

Figure 33: The timeline of the district-based learning community

Sept/Dec 2017	• Leader network meetings
January 2018	• Department Chair, Math State Department of Education Leader, BMTN Network Leader collaborate to start a district-based learning community
Spring 2018	• Three district-based meetings include algebra teachers from high school and both middle schools in the district • Teachers try out two new BMTN-created routines in their classrooms in between meetings

The structure of Year One of the district-based learning community

Mary Lou shared the idea of the learning community with her principal and superintendent, who were interested. She then brought together teachers from her school and the district's middle schools for three meetings. The first meeting was held in February after school. In April and May, the teachers took a full day out of school (the network paid for substitute teachers). On those two days, Mary Lou worked with the teachers on district math projects in the morning and Gail joined in the afternoon to engage the teachers in the BMTN work. The state math leader joined the meetings and learned alongside the teachers. In all, nine teachers joined the learning community—four high school and five middle school math teachers.

Gail worked with teachers in the first meeting to develop an understanding of:

- The problem that BMTN is tackling

- The aim that guides the improvement work

- The improvement science approach, and specifically the PDSA inquiry cycle

- How to use PDSA testing to try out some routines produced by BMTN teachers

At the end of the meeting, Gail asked the teachers to go back to their classrooms and engage in a PDSA cycle using a BMTN teacher's routine: *Non-Rote Problems*. The BMTN teacher, Ellen, built a formative assessment problem-solving routine to provide opportunities for students to work on challenging non-rote problems. In between the first and second meetings, teachers tried out a PDSA cycle using the new routine in their classrooms.

When the group met again in April for their second meeting, Gail spent time engaging teachers more deeply in the PDSA process, helping the teachers to think about:

- How does the PDSA process help you make decisions about the routine you are testing?

- What does your data tell you?

- What do you observe in terms of quality and depth?

- What modifications (if any) should you make?

Teachers brought data and student work to share with their colleagues in the second meeting. As they looked at their student work, they grappled with how to define depth. They did not yet have the rubric that Ellen had refined for use in the routine. This allowed the teachers to have deep conversations about what depth meant for them as they collaboratively looked at their student work.

In addition, the teachers realized that—as a district—they did not have a set of problem-solving strategies that students used throughout middle school and high school. They discussed ways in which teachers could model strategies for students on a more regular basis, connecting problem-solving strategies with the tasks they were working on in their PDSA cycles. After the meeting, Mary Lou sent the teachers pictures of the posters she used when teaching problem-solving strategies to her students. Mary Lou and the teachers agreed to focus on problem-solving strategies across the math curriculum the following year.

At the end of the second meeting, teachers were introduced to a new routine, also designed by a BMTN teacher: *Using Written Examples to Help Students Explain Thinking*. The hub leader gave teachers the choice to either continue to test out the first routine in their classroom or try the new one. She also gave them the rubric that Ellen had designed and tested as part of her *Non-Rote Problem* routine. The rubric is a tool for students to assess their own depth of engagement. Gail asked teachers to fill out another PDSA form as they engaged in their inquiry cycle. When they met in June, Gail continued to help them think about how to use the PDSA process to make decisions about the routine they were testing, focusing on the data they collected and what it told them.

Throughout the meetings, Gail balanced new learning with sharing and discussion. Teachers engaged in the discussions and shared their work and experiences with each other. In addition to discussions about their PDSA cycles, there were lively discussions about their students' learning needs, challenges they faced in their teaching, what tasks they were using in their classrooms, and how to build coherence in their district.

By design, the district learning community had less training on improvement science compared with what network leaders provided to the BMTN teachers. For some, what they learned about improvement science in the first meeting was enough. A few noted they would have liked to learn more. Even so, some teachers seemed to "get" enough of the essence.

> **"** *You guys have a great process. The PDSA seems to be a really effective cycle in the way of doing things. ... It kind of pinpointed for me that you do the DSA part really well, but the planning part is something I definitely need to work on. I've always kind of been a fly-by-night kind of guy. I'm good like that in the sense that I can come up with a lesson plan quickly or I can create an assessment very well, in my opinion, on my own without having other supplements or other people helping me out. But at the same time, I definitely need to put more time into the planning piece."*

> **"** *I think is pretty self-explanatory, the concept. You know, the idea behind it is to do what you're doing. It's to collect data, to interpret data. It's to improve on concepts and ideas and procedures that are the foundation for how we are teaching and how we're doing things. So, I kind of—I get it in concept."*

In addition, network leaders intentionally designed the learning community so that teachers would try out an already tested and refined routine, with the option to use a rubric that was designed and refined for that routine. This allowed teachers to:

- skip the step of deciding what to change in their own practice
- have access to a practical measure to assess whether the change led to an improvement in student engagement
- engage in joint work with colleagues implementing the same routine
- focus on testing, analyzing data, and making decisions about next steps
- compare experiences across different classrooms and schools

It also provided an opportunity to spread the routine, another goal of the pilot. A few teachers mentioned the adjustment to their own teaching that was necessary in order to implement someone else's routine into their practice, but even those teachers were excited to engage students in these different, more student-centered approaches.

> *It was nice to have a structured routine that was a step-by-step on what they had to do, how they had to do it exactly, and then [getting] feedback and rubrics to go along with the task."*

> *I think it provides a lot more structure to be given a model. I wouldn't have learned how important it is to teach the routine before actually using it if I did it on my own, so I see a really big benefit to be given the routine. I feel the benefit of working on the same routine so we could all reflect together."*

> *For me that was helpful that we were all doing the same thing, so you could really compare the data. If I just had one group, I think the data would be skewed because I don't have the type of kid that somebody else has."*

Both the middle school and the high school teachers appreciated the opportunity to work cross-level.

> *Then we [the high school teachers] can get a better feel, too, for where our students are coming from, or then they can see what's expected of them, and where they're going. I just really like it because they're in a different environment than we are, so things are happening in a different way. I like to compare them."*

Benefits of engaging in the learning community

In general, teacher responses to their experience in the learning community were overwhelmingly positive. In interviews, they noted the following benefits:

- Opportunity to collaborate with other math teachers in the district, including teachers from another level (middle school and high school)

> 66 *It was useful because we got to talk to the other math teachers, which we don't usually get to … like the high school teachers and even the other middle school teachers. And we talked about the problems that we did, because a lot of us did the same problems."*

> 66 *I find it really useful when algebra teachers or geometry teachers can really have that time to collaborate and share new strategies that might work for them or their population."*

> 66 *The focus was very concise, and we were happy that we are able to all get together and discuss such important things. Because really, aside from the administrators in our buildings, we don't necessarily discuss our teaching strategies as much as resources or the day-to-day tasks with our peers."*

- Accountability and investment

> 66 *This [opportunity] is different because the teachers have to do something and come back and report on it. There is investment. If they didn't want to do it, then they wouldn't have come back with work. They would have just said, "I can't come." The teachers that you saw, it was evident that they are invested in it. They came back with work. They were able to discuss the work. And to me, that is ownership and interest and motivation."*

- Opportunity for novice teachers to learn from more experienced teachers

> *For me it's really helpful to hear the perspective of more experienced teachers. I talk about what I've learned and what happened, and they can help me get a different perspective on it that I wouldn't know yet because I'm a new teacher."*

Challenges teachers faced in the learning community work

Teachers in the learning community faced some of the typical challenges related to this work, including the difficulty of getting pulled out of class to meet, finding the extra time it takes to do the work, and starting new routines midyear.

> *There were a lot of interruptions where if you lay out the scope and sequence and the plans that we had laid out throughout the year for pacing and fluency. It was tough to kind of fit in the time, albeit necessary time, for students to engage in a process like this. It's different than what we are used to. So that ... was the biggest challenge, trying to get this in and make time for it with everything that was going on."*

> *I don't know how other people feel about professional development, but I do not like to leave my classroom. Because then when I get back, nothing was done that I wanted to be done. And then I'm stepping—I'm taking a step back, because I have to review with them. I don't like that."*

Some teachers mentioned the time it took to fill out the PDSA documentation. In fact, very few teachers turned in their PDSA forms, despite this being an expectation set by Gail. Some teachers did not know how to fill out the form, while others had technical trouble (e.g., not knowing how to access it digitally, unable to figure out how to send it to Gail).

What teachers learned by engaging in the learning community work

Teachers reported learning a variety of things from their engagement in the learning community. Several teachers appreciated that the community helped them to feel like they were not alone in trying to get their students to engage in math. For three teachers, the work helped them think differently about how to use data to improve their instruction.

> **❝** *I really think I've learned how to read data or how to interpret that data. Instead of taking a student and saying, "Okay. They know this strategy. I'm going to put them in this pile. These kids don't know and I'm going have to go over it again," I'm not doing that. I'm looking at actually what they did and saying, "Okay. I'm going to pair them up with this student who got it right and then let them talk together to come up with a compromise of how they both could solve the question."*

> **❝** *I'm very good at looking at outside measures of data, standardized tests. But looking at your own data, that was a new approach to me."*

> **❝** *I think those skills; how to make something better—that's the theme that I get from Better Math Teaching Network. If you want to make something better, then focus on it and just collect the data and define it. Figure out what's wrong."*

Another important learning this work brought to several teachers (and a reminder in the case of one veteran teacher) was the need to do more complex tasks.

> **❝** *Trying to fit in these quality tasks that allow students to dig deeper into the concepts and reach for tools that they've either learned or might be learning that—it needs to just be more of a part of the weekly process in the classroom."*

As they tried out and discussed their use of similar tasks, teachers identified tasks that worked better at the high school level or middle school level.

Conclusion

AIR-based hub network leaders designed the learning community pilot as a way to test a model for spread: might teachers be able to accelerate their learning by taking up routines developed and tested in other contexts? Could they productively engage in inquiry cycles with less upfront training in improvement science and less ongoing support than the full BMTN network model? In this pilot:

- The learning community engaged math teachers from the district's high school and middle schools.

- Teachers ranged in experience from first year to veteran status.

- This was the first time most of the teachers had collaborated with district colleagues who did not teach in their own school.

- The math leader utilized the opportunity to have all of the teachers together to work on district matters prior to the start of two of the three learning community meetings.

- All of the teachers tried out at least one routine in their classrooms.

- There were varying degrees of data collection, analysis, and documentation completed.

There were two main trade-offs of this design compared with the BMTN model: all teachers engaged in the same routine rather than designing their own work and these teachers learned less about improvement science than the BMTN teachers. While it is too early in the work to know definitively, early evidence points to the payoff in simplifying the BMTN message. Teachers were universally happy to be given a routine to try out in their classroom and a rubric to use to assess student work. They appreciated the joint work and opportunity to dig into the student work and measurement piece. They spent less time both generating a change idea and grappling with what makes a good practical measure. In this first year, much of their discussion focused on:

- challenges with students (e.g., it was new for many of the teachers to engage their students in non-rote tasks so there was a learning curve for them and their students),

- challenges with finding good tasks, and

- building coherence between middle school and high school math in the district.

As the learning community enters its second year, all but one of the teachers from Year 1 are returning and six additional teachers (from each of the three schools) will join. Mary Lou has set two goals for the work in Year 2: to continue to focus on problem solving across the grades and to increase SAT/PSAT scores. When the math team at the high school looked at the item analysis of their students' SAT scores, they noticed their students struggled the most with word problems. Mary Lou will use the learning community as a place for teachers to collaboratively work on this challenge as they provide more opportunities for students to solve with quality and persevere through hard problems. The teachers new to the group will kick off their work in December, and the returning teachers will join for three meetings in January, February, and March. We are interested to learn more about how this work spreads and deepens, changing teaching practice and student engagement in math in grades 6–12.

Conclusion

The Better Math Teaching Network seeks to increase opportunities for high school students to deeply engage in algebra. Teachers in the network are highly engaged; they spend time outside of their typical teaching duties to attend quarterly network meetings and engage in quarterly inquiry cycles supported by virtual small-group meetings. Some BMTN teachers participate in optional study group meetings, support the network through leadership roles, and spread what they are learning beyond the network. Seeking to improve their own practice, BMTN teachers learn from each other and from network leaders. As the network moves into its third full year, it is poised to consolidate learning from several years of PDSA testing, build structures to spread that learning beyond network members into their schools, districts, and new districts, and inform the field on what it takes to grow and sustain an instructionally-focused networked improvement community.

Glossary

BMTN: Better Math Teaching Network
The Better Math Teaching Network is a networked improvement community (NIC) 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.

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, 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. Identifying hypotheses, testing those hypotheses, and comparing results with one's predictions generates new details about one's 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 that is defined as: "A tool 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

In order 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 (Algebra I) content and a Hub lead with research and practical expertise in mathematics teaching and learning as well as improvement science expertise.

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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 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.

Table 1A: Data sources and number of administrations and respondents

Data sources	Data collected
Network leader self-assessment survey	N=3 May administration to all network leaders
Network member survey	41 teachers December; 38 teachers June
Teacher interviews	40 teachers December; 38 teachers June
Observation and artifacts from network in-person meetings	Field notes and artifacts: July, October, December, May
Small group, PDSA coaching meetings videos	N=47
PDSA documentation	
Cycle 1 drafts	N=36
Cycle 2 drafts	N=35
Cycle 3 drafts	N=33
Cycle 4 drafts	N=26
Change idea summaries	N=34
Change idea summary presentations	N=29
Study group meeting videos	N= 18 (video from 3 groups)
Study group meeting notes	N=38 (notes from 7 groups)
BMTN case studies	
Classroom observations	N=8
Case study teacher interviews (BMTN)	N=16
Case study teacher additional artifact documentation	24 artifacts of change in practice
LC Case study	
Meeting observations	Field notes and artifacts: February, May Artifacts: April
Case study teacher interviews (LC)	N=6
Case study leader interviews	N=2

Analytic approach

Survey data of 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 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, school-based meetings, and coaching meetings were analyzed using thematic analysis tethered to our guiding evaluation questions.

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.

All photos: Nellie Mae Education Foundation

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