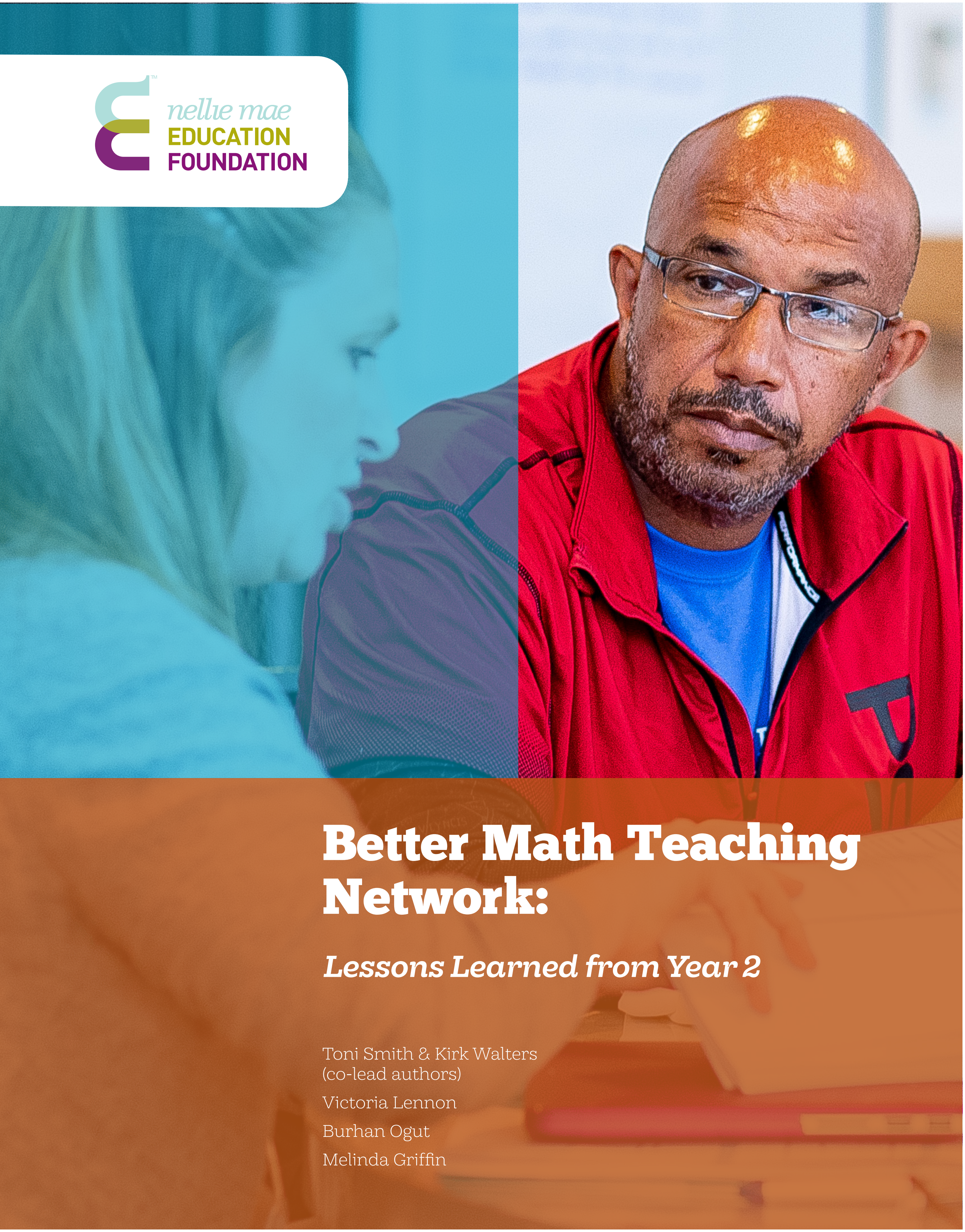

Better Math Teaching Network:

Lessons Learned from Year 2

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Report Summary

The Better Math Teaching Network (BMTN) is a networked improvement community of researchers, teachers, and instructional leaders from New England who use improvement science principles to increase the number of students who are actively and deeply engaged in algebra content. The BMTN's second year of implementation occurred during the 2017–18 school year. Key findings include:

- Continued high teacher participation and engagement. As with the first cohort, BMTN teachers actively participated in roughly 100 hours of individual, small group, and whole group network activities.
- Increased opportunities for deep student engagement. As reported both by teachers and students, BMTN classrooms provided increasing opportunities for students to deepen their understanding of algebra over the course of the 2017–18 year.
- Progress made towards achieving the network aim. The BMTN made steady progress towards meeting its aim of increasing the number of algebra students who connect, justify, and solve with depth.
- Continued deepening of student-centered instruction. Through math content study groups, the selection of instructional tasks, and the testing of instructional routines, BMTN classrooms had a stronger focus on developing mathematical relationships.
- Experienced BMTN teachers key to spreading network learning. Through their interactions with new BMTN members and the sharing of refined instructional routines, returning BMTN teachers helped accelerate the learning of new BMTN teachers and share the work of BMTN to teachers outside the network.

The Better Math Teaching Network

The Better Math Teaching Network (BMTN) is a networked improvement community (NIC) of researchers, teachers, and instructional leaders who share a common aim: to increase the number of students in New England who deeply engage in algebra content. The heart of our network is high school algebra teachers, who actively test, refine, and share instructional routines that are aligned with our network aim. These teachers, who represent every state in New England, primarily work in rural or urban schools and work with economically disadvantaged students. A research team from the American Institutes for Research (AIR) comprises the hub and leads the network, which consisted of 51 teachers and 10 instructional leaders during the 2017–18 school year and is the focus of this report.[1]

Our work is guided by principles of improvement science, an applied scientific approach designed to help organizations solve complex problems and improve performance through iterative, rapid-cycle testing.[2] Though used in recent decades in industries outside of education, this approach is relatively new to education.[3] Unlike interventions that focus on achieving high levels of fidelity and consistency of implementation, improvement science focuses on understanding variation in implementation. Improvement scientists expect variation in implementation and view it as an opportunity to target ongoing improvement efforts and further strengthen implementation. Thus, BMTN teachers approach their work with the understanding that even well-conceived, well-implemented instructional routines will fail at certain points in the lesson. Those failures provide opportunities to further strengthen the routine the next time it is implemented.

Our NIC is structured so that teachers and researchers collaborate frequently—both in person and virtually—to share what is being learned through the testing and refinement of instructional routines, and to identify resources and supports for ongoing improvement. BMTN teachers participated in about 100 hours of organized in-person and virtual meetings during the 2017–18 school year and many reported spending more time informally collaborating with other network members outside of network meetings.

Building on broader research in mathematics education,[4] including a study carried out previously by the members of the network hub,[5] our network has identified three domains of deep student engagement that comprise our aim. Though not mutually exclusive, BMTN teachers focus their improvement efforts on one of these three domains: *connect*, *justify*, and *solve*.

- ***Connect.*** Making connections among mathematical algorithms, concepts, and application to real-world contexts, where appropriate.
- ***Justify.*** Communicating and justifying mathematical thinking as well as critiquing the reasoning of others.
- ***Solve.*** Making sense of and solving challenging math problems that extend beyond rote application of algorithms.

Promoting deep student engagement in these three areas runs counter to standard practices in U.S. math classrooms, which tend to focus more heavily on developing students' procedural skill through teacher-directed approaches. We aim to use student-centered approaches to develop students' ability to make connections, justify their thinking, and solve complex problems.[6] We focus on these three domains within algebra, considered a STEM "gatekeeper" course, to support larger efforts to improve U.S. student achievement in mathematics[7] and increase the number of U.S. high school graduates who are prepared to fill the hundreds of thousands of unfilled STEM-related jobs in the U.S.[8]

In the remainder of this report, we describe activities and progress made this year towards achieving our network aim. First, we present our formal network aim and the improvement science tools and methods that guide our work. Next, we describe the instructional routines that teachers tested throughout the 2017–18 school year in support of the aim, before describing the progress made towards achieving our aim. Then, we present two sets of lessons learned from network activities. The first set relates to lessons about student-centered math instruction, and the second set relates to lessons about how improvement knowledge is spread in the context of a network. We conclude with a summary of next steps for the 2018–19 school year, our third full year as a network.

Network Aim and Driver Diagram

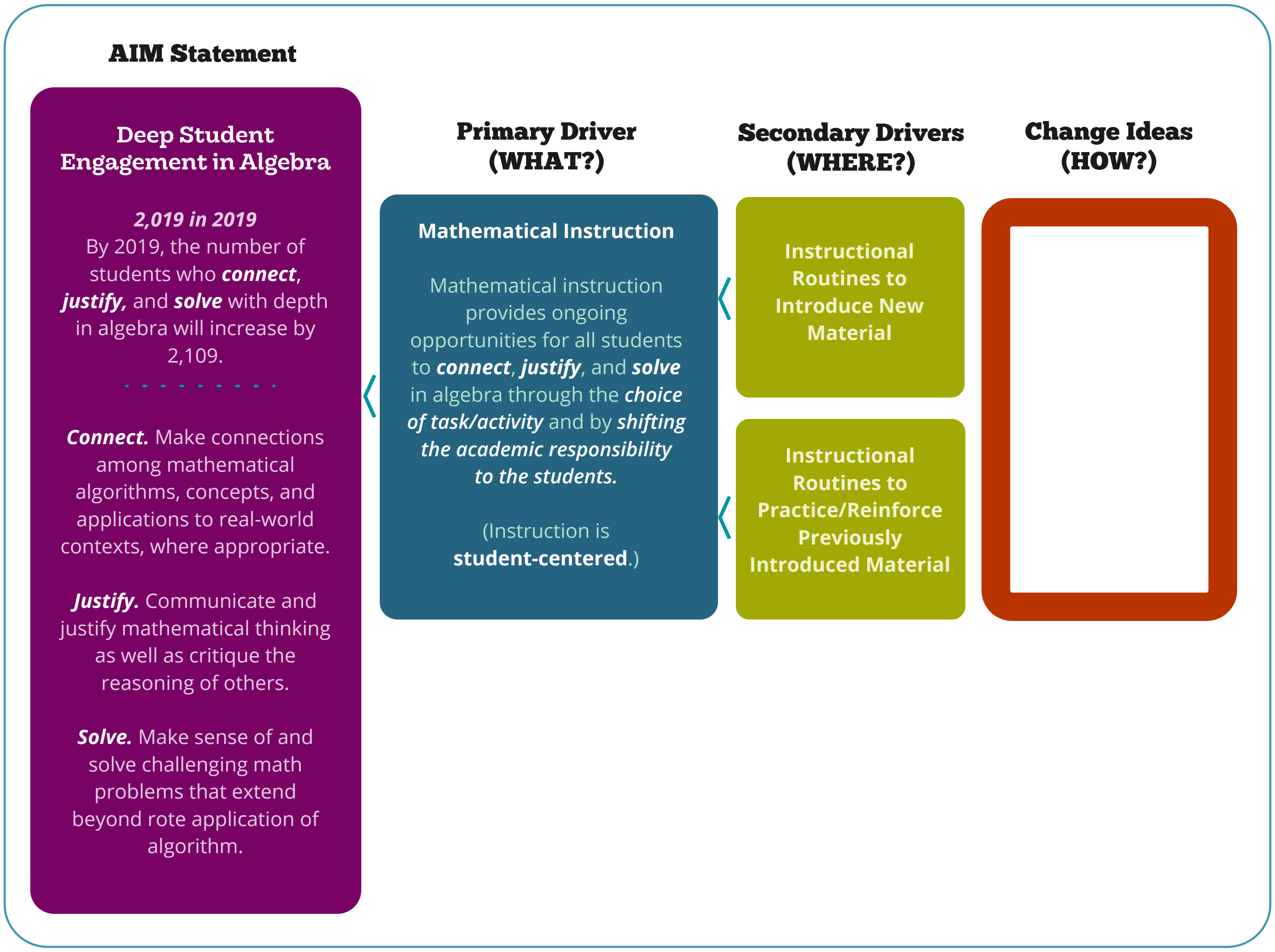
NICs are organized around a **common aim**, which the network co-constructs during its initial phase of development. By 2019, the BMTN aims to increase the number of New England students who *connect*, *justify*, and *solve* with depth by 2,019. We selected this number of students when we launched our three-year network based on the projected number of teachers and students who would ultimately participate.[9]

BMTN Aim Statement

By 2019, the number of students who *connect*, *justify*, and *solve* with depth will increase by 2,019.

Our efforts to meet this aim by the spring of 2019 are based on a common, working theory of improvement, called a **driver diagram**. A driver diagram is a visual tool that NICs use to illustrate the network's working theory of improvement as it relates to the network's aim.[10] It also provides a common language to frame the improvement work. Given the network's focus on teachers, we identified math instruction as our primary driver (see Exhibit 1). We hypothesize that when teachers provide ongoing opportunities for students to *connect*, *justify*, and *solve* with depth, we will make progress towards our aim. Two key dimensions of this work are the tasks teachers use with students and the extent to which students assume responsibility for academic content. Because we anticipate the tasks and strategies for shifting academic responsibility to students to differ for activities focused on introducing students to new material and activities focused on practicing previously introduced material, we focused our secondary drivers on those aspects of instruction. Teachers develop change ideas—in our case, specific instructional routines—that they hypothesize will increase the depth of student engagement and are aligned to the primary driver and at least one secondary driver.

Exhibit 1. BMTN Driver Diagram

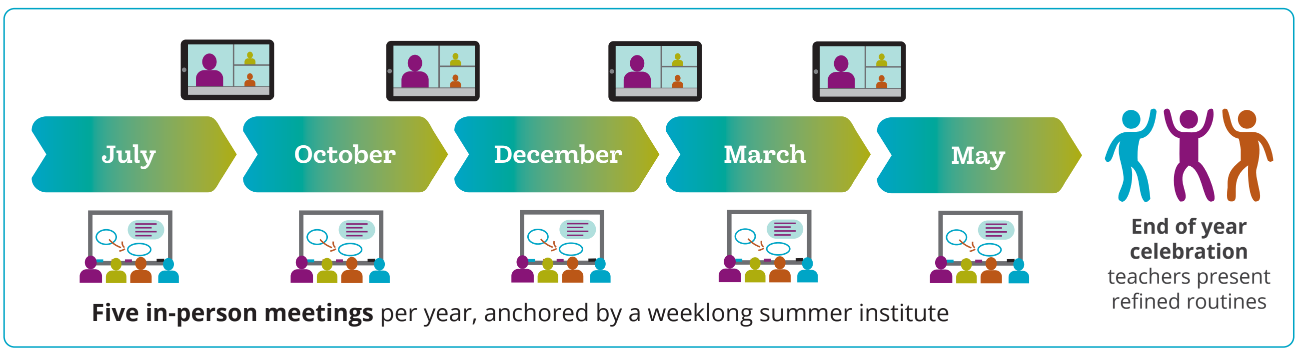


After teachers select change ideas they think will lead to improved student engagement, they subject these ideas to rapid-cycle testing in their classrooms. The testing follows the **Plan-Do-Study-Act (PDSA)** improvement science process, which is framed by three questions teachers ask themselves each time they test out an idea: (1) Will I implement the instructional routine as planned? (2) Will students engage in the activities associated with the instructional routine? and (3) Will students engage with depth? During the **Plan** phase, teachers create a specific plan for how they will implement the routine and collect data on the three framing questions. They also make predictions for what they might see in the data. In the **Do** phase, they execute the planned routine and collect associated data. They also note any immediate reactions to the activities as implemented. During the **Study** phase, teachers carefully analyze the data, compare it to their predictions, and determine what to do next. In the **Act** phase, teachers decide whether to adopt the instructional routine as is, adapt it in some way, or abandon it altogether.

Network Learning Structures

When teachers join the BMTN, they participate in a weeklong summer workshop where they learn the basics of improvement science and PDSA testing, get oriented to the network aim and vision of student-centered instruction, and plan for the upcoming school year. Returning BMTN members join the new members partway through the summer workshop to share their experiences, discuss instruction, and collaboratively plan for PDSA testing. When the school year begins, new and returning teachers begin to test their change ideas with PDSA cycles. They typically complete 3-5 PDSA trials over a 4–6 week testing period. After each testing period, they meet virtually with a small group of teachers who are working on a similar change idea within *connect*, *justify*, or *solve*. During these meetings teachers discuss how similar routines played out in different contexts, share what they learned from the data they collected, and get feedback from others on the Act phase. These small-group meetings are typically followed by a whole-network, in-person meeting. The whole-network meetings provide a larger forum for teachers to share what they are learning outside their smaller groups and for the hub to provide professional development support on emerging issues as needed. This process of individual testing followed by small-group and whole-network meetings repeats three times over the course of the school year. At the end of the school year, teachers present their refined instructional routines at a celebratory mini-conference. These refined routines are then written up and shared with the next cohort of BMTN teachers during the following summer workshop. Exhibit 2 summarizes these activities over a typical school year.

Exhibit 2. PDSA Testing Process and Timeframe



Instructional Routines Tested in 2017–18

During the 2017–18 school year, BMTN teachers tested and refined a variety of instructional routines designed to deepen student engagement with algebra content. The routines focused on *connect*, *justify*, or *solve* and at least one of the network's secondary drivers: the introduction of new material or the reinforcement of previously introduced material. Exhibit 3 lists the six instructional routines BMTN teachers tested and refined that focused on deepening students' mathematical connections. Three of the routines were designed for the introduction of new material, one was designed for reinforcement of previously learned material, and two were designed to work in either context.

Exhibit 3. Instructional Routines Focused on Connect, 2017–18 BMTN Teachers

Instructional Routine: Connect	Secondary Driver	
	Intro	Reinf.
Reminding students of the big ideas of the unit to support connections	✔	
Using a template and class discussion to emphasize connections	✔	
Using tasks and guiding questions to support students in making connections through the introduction of new material		✔
Eliciting connections through probing questions	✔	✔
Exit routines to build mathematical connections	✔	✔
Introducing new material by making connections with students' previous knowledge	✔	

DATA SOURCE: BMTN teacher change idea summaries, 2017–18 school year.

Our teachers most commonly focused their improvement efforts on supporting students in justifying their thinking and critiquing the reasoning of other students with greater depth. As illustrated in Exhibit 4, teachers tested and refined 21 different routines in this area, with the majority aligned to the reinforcement of previously introduced material (16 routines) and the remaining 5 designed for use with the introduction of new material. Unlike the routines focused on *connect*, none of the routines focused on *justify* targeted both secondary drivers.

Exhibit 4. Instructional Routines Focused on Justify, 2017–18 BMTN Teachers

Routine	Secondary Driver	
	Intro	Reinf.
Using claim-evidence-reasoning to support strong justifications		✔
Using open-ended, scaffolded tasks to help students develop and justify strong claims	✔	
Using a structured talk protocol to support justifications		✔
Infusing opportunities for justification in math tasks		✔
Using comparison tasks to improve justifications		✔
Using non-rote problems to improve student justifications		✔
Using tasks and a structured whole-class discussion protocol to support justifica-tions	✔	
Asking students to order statements to make strong justifications		✔
Using a small-group protocol to promote deep justifications		✔
Communicating deep learning from inquiry-based activities	✔	
Using "Which One Doesn't Belong" activities to support deep justification		✔
Using a protocol and poster template to promote justifications		✔
Using a problem-solving protocol to support deep justifications		✔
Using strategize, demonstrate, and explain to support deep justifications		✔
Critiquing worked examples to improve justification skills		✔
Using small-group work to improve verbal justifications		✔
Introducing new material with examples to support justification	✔	
Sentence frames to support justification		✔
Using a justification worksheet to support justification	✔	
A partner share protocol to promote deep justifications		✔
Tiered checkpoints to promote justifications		✔

DATA SOURCE: BMTN teacher change idea summaries, 2017–18 school year.

Finally, as presented in Exhibit 5, BMTN teachers tested and refined nine instructional routines during the 2017–18 year that focused on solving with depth. Only one of the *solve* routines targeted the introduction of new material exclusively, while four routines each targeted the reinforcement of previously introduced material or both secondary drivers.

Exhibit 5. Instructional Routines Focused on Solve, 2017–18 BMTN Teachers

Instructional Routine: Solve	Secondary Driver	
	Intro	Reinf.
Protocol to support small-group problem solving		✔
Guiding questions to support problem solving	✔	✔
Assigning roles and a protocol to support small-group problem solving	✔	✔
Using challenging homework problems to promote skill in problem solving		✔
Small-group problem solving protocol to promote depth	✔	✔
Scaffolding and solving cognitively demanding tasks to encourage problem solving		✔
Providing prompts for adults providing student support in math class to encourage problem solving	✔	
Using protocols to support students in making sense of non-routine problems & explaining approach	✔	✔
Daily mindfulness time in math class to promote problem solving		✔

DATA SOURCE: BMTN teacher change idea summaries, 2017-18 school year.

Assessing Progress Towards the Aim

As illustrated in BMTN's driver diagram, the ongoing testing, refinement, and sharing of instructional routines is meant to stimulate deep student engagement in algebra. By 2019, which is the third year of our network, we aim to increase the number of students who deeply engage in *connect*, *justify*, and *solve* by 2,019. Our primary method for tracking progress towards the aim is a student survey, in which we collect information about how often students are deeply engaged with algebra content. In addition, to assess progress on providing opportunities for deep engagement through math instruction (our primary driver), we administer a teacher survey to the BMTN teachers. In this section, we present findings from both surveys.

Network Making Progress Towards Aim

The student survey consists of 15 items which ask students how often they are engaged in activities that are aligned with *connect, justify*, or *solve*. Five items address activities associated with *connect*, five items address activities associated with *justify*, and five items address activities associated with *solve*. In reporting engagement in the activities, students choose from *Never*, *Rarely*, *Sometimes*, *Often*, and *Almost Daily*. Exhibit 6 lists the survey items along with the reliabilities (Cronbach's Alpha) for these items by domain.

Exhibit 6. BMTN Student Survey Items, Constructs, and Reliabilities[11]

Survey Items by Construct and Overall	Cronbach's ∝
Connect. *How often…*	.80
Do you make sense of mathematical rules, concepts, and relationships?	
Do you make connections to math concepts from other classes you've taken before or in the future?	
Do you make connections between math and real-world situations?	
Do you examine why the steps to solving a math problem or following a procedure work?	
Do you make connections to math concepts you learned previously in this class?	
Justify. *How often…*	.82
Do you explain your answers to others in the class?	
Do you argue or defend your approach to solving math problems?	
Do you critique the mathematical reasoning of others—either written or spoken?	
Do you evaluate other students' approaches to solving math problems?	
Do you discuss possible solutions to math problems with other students?	
Solve. *How often…*	.78
Do you keep trying different ways to solve math problems even when they are hard?	
Do you re-read or go over a math problem again if you have trouble understanding it?	
Do you keep working on math problems even when you are stuck?	
Do you determine if your answers to complex math problems make sense?	
Do you solve math problems with multiple steps that take more than 20 minutes to solve?	
Overall	.91

DATA SOURCE: BMTN Student Survey, 2017–18 school year.
NOTE: We dropped the last item in the Solve domain due to low item-test correlation and alpha—both for this domain and overall.

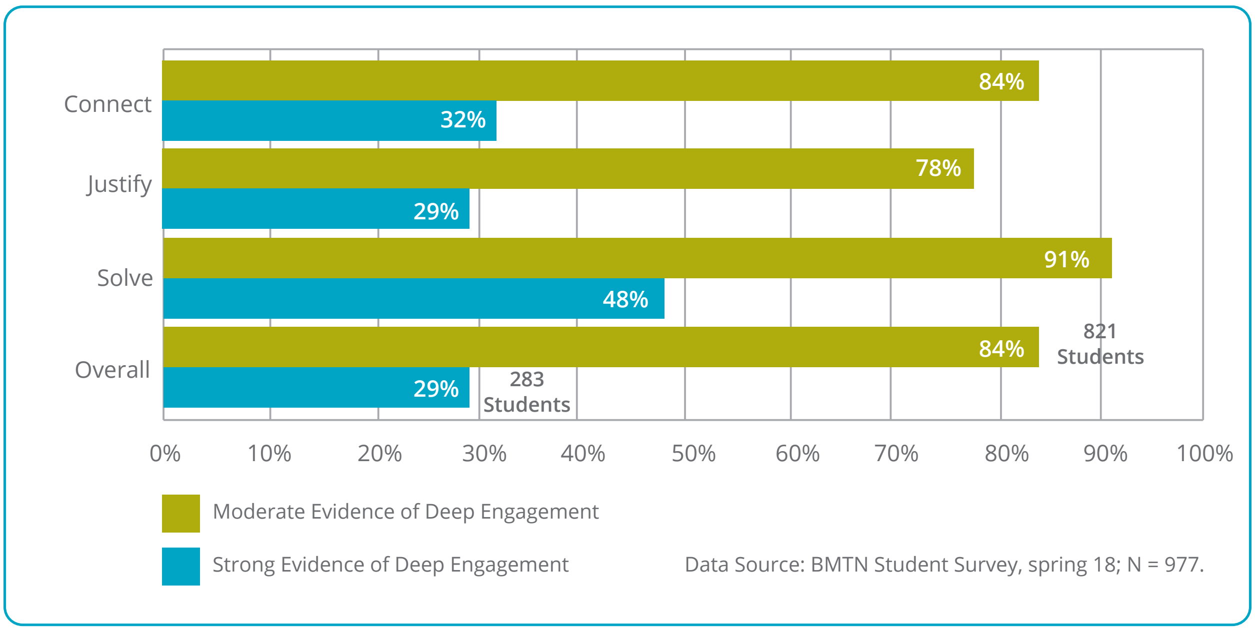
To compute reliabilities, we assigned 1 point to *Never*, 2 points to *Rarely*, 3 points to *Sometimes*, 4 points to *Often*, and 5 points to *Almost Daily*. As illustrated in Exhibit 6, the reliabilities for each domain and overall are high. Only one of the 15 survey items—"Do you solve math problems with multiple steps that take more than 20 minutes to solve?"—was dropped from these analyses because it was poorly correlated with the other survey items.

To assess progress on the aim by domain and overall, we established criteria for "deep engagement" from the activities specified in the student survey. Survey response options *Never* and *Rarely* clearly indicate limited opportunities for deep student engagement, and *Often* and *Almost Daily* indicate more extensive opportunities for deep engagement. However, *Sometimes* could also be an appropriate expectation for several of the activities, even in highly student-centered classrooms. For example, we do not necessarily expect students to "make connections to math concepts from other classes or in the future" *Almost Daily* or *Often*. The nature of the topic may not lend itself to daily discussion of connections to other classes or future work. We do, however, think that students should be making those types of connections at least some of the time. In addition, if a teacher focuses her improvement work on *justify*, we might expect student responses to those items to be higher at the end of the year than for the items associated with *connect* or *solve*.

Given these considerations, we determined that responses that average 4 or higher within a domain or higher on the survey overall provide **strong evidence** of deep student engagement and responses that average a 3 or provide **moderate evidence** of deep engagement.

Exhibit 7 shows the progress that the network made towards meeting its aim during the 2017–18 school year. At the end of the school year, about 84 percent of students reported an average of 3 or higher (moderate evidence of deep engagement) across the items on the survey. This represents 821 students across BMTN classrooms. Among this group, 283 students reported an average of 4 or higher, providing strong evidence of deep engagement in algebra. More students reported deep engagement with *solve* than for *connect* or *justify*. A total of 91 percent of BMTN students reported an average of 3 or more and 48 percent reported an average of 4 or more.

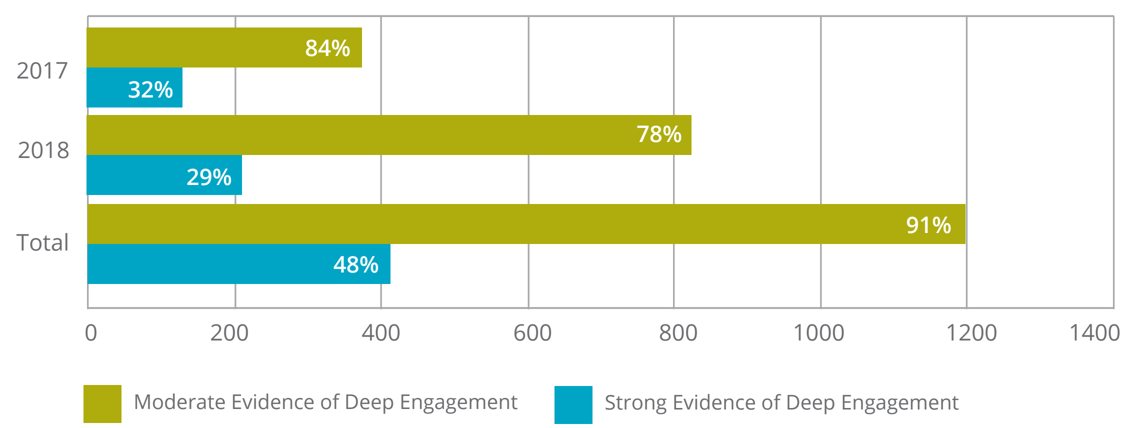
Exhibit 7. Percentage and Number of Students Deeply Engaged in Algebra, by Evidence Level and Dimension, 2017–18 School Year



DATA SOURCE: BMTN Student Survey, spring 18; N = 977.

When we look at student engagement across the two years of the network (2016–17 and 2017–18), we can see our progress in reaching the aim. Exhibit 8 shows the number of students who reported an average of 3 or higher and 4 or higher on the student survey overall in 2016–17, 2017–18, and in total. Across the two years, a total of 1,197 students provided at least moderate evidence of deep engagement in algebra. This is 59 percent of the 2,019 students we aim to deeply engage with algebra by the year 2019. A total of 413 students (21 percent of 2,019 students) provided strong evidence of deep engagement. As the network moves into the 2018–19 school year, with additional teachers and students in the current cohort, the BMTN is well positioned to meet its aim by 2019 at the moderate level of evidence and increase the number of students at the strong level.

Exhibit 8. Number of Students Deeply Engaged in Algebra, by Evidence Level and Network Year



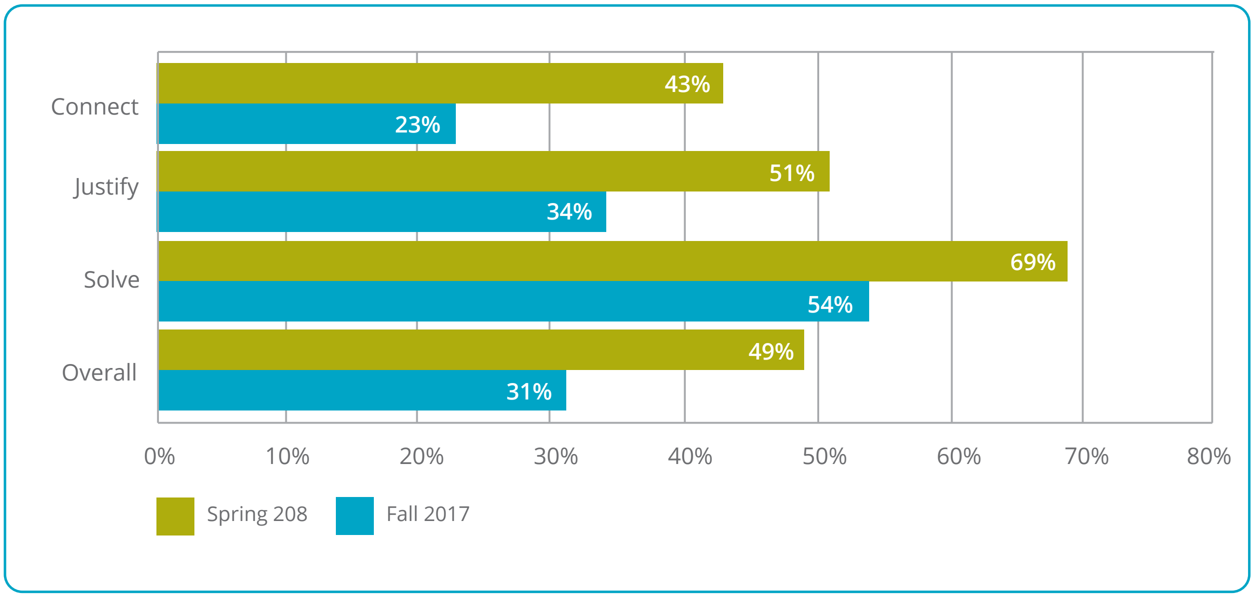
DATA SOURCE. BMTN Student Survey, spring 2017 (N = 977) and spring 2018 (N = 447).

Teachers Increased Opportunities for Deep Student Engagement

As a process measure of the extent to which our teachers are providing opportunities for deep engagement, we also surveyed teachers about the frequency that they provided students with the specific opportunities students reported on the student survey. For example, where the student survey asks, “How often do you make sense of mathematical rules, concepts, and relationships?” the teacher survey asks, “How often do you *provide students with opportunities* to make sense of mathematical rules, concepts, and relationships?“ The response options on the teacher survey were the same as for the student survey: *Never, Rarely, Sometimes, Often,* and *Almost Daily*. Like on the student survey, we consider an average score of 3 or more to provide moderate evidence of opportunities for deep engagement and a score of 4 or more to provide strong evidence of opportunities for deep engagement.

All BMTN teachers indicated that they offered the opportunities for student engagement in each of the 15 items at least *Sometimes*. This is encouraging but perhaps expected given the active involvement of teachers in PDSA testing during the 2017–18 school year. Also, as illustrated in Exhibit 9, the percentage of teachers who reported strong evidence of providing opportunities for deep engagement varied by the time of year of the survey (Fall or Spring) and the domain of engagement (*connect*, *justify*, or *solve*). By domain and overall, the percentage of teachers who offered students deep opportunities for engagement at the strong evidence level increased from fall to spring, with almost half of BMTN teachers (49 percent) providing such opportunities in spring 2018. Among the domains, like the student survey, *solve* had the strongest evidence, with almost 70 percent of BMTN teachers reaching the strong level by Spring 2018.

Exhibit 9. Percentage of Teachers Providing Opportunities for Deep Student Engagement at the Strong Level, Fall to Spring, 2017–18 School Year



DATA SOURCE: BMTN Teacher Survey, 2017–18 school year, N = 35.

Lessons Learned

As described in our report about the network's first year of implementation, we completed the chartering phase of NIC development at the end of the 2015–16 school year and moved into the network learning phase in 2016–17. In the **chartering** phase, we convened a small group of researchers and practitioners to define the problem and determine the way in which we would address it through a NIC.[12] During the **network learning** phase, we used PDSA cycles to test and refine student-centered instructional routines and began to consolidate our learning, which we continued into 2017–18 and described earlier in the report. As we moved further into this phase in 2017–18, we also began to move into the final phase of NIC development: **spreading knowledge** gained through PDSA testing with other teachers inside and outside of the network. In this section, we present what we learned this year about student-centered instruction and how to support the spread and continued testing of instructional routines that support deep student engagement with algebra.

Lessons Learned Related to Student-Centered Instruction

This year's testing of instructional routines drew upon what we learned about student-centered instruction the previous year, namely that instruction should include tasks and scaffolds that provide opportunities for deep engagement in making connections, justifications, and solving non-rote problems. As new and returning teachers tested and refined instructional routines during the 2017–18 school year, they used tasks and scaffolds to support deep student engagement. Through that testing, teachers learned more about the nature and implementation of the tasks and scaffolds that are needed to improve the depth of students' connections, justifications and problem-solving processes. Specifically, our teachers learned that they needed to:

- Focus instructional tasks and activities on mathematical relationships, as opposed to rote procedures;
- Use questions that explicitly address math relationships to assess the depth of student connections, justifications, or problem-solving processes;

- Allow time for students to work individually to gather their thoughts before working with other students;
- Provide opportunities to see examples of, practice, and receive feedback on their attempts at deep engagement; and
- Make sure they had a deep understanding of the content themselves to design and implement instruction with these features.

Whether working on *connect*, *justify*, or *solve*, teachers found that the more the tasks and other instructional activities focused on mathematical *relationships*, the greater the opportunity for students to demonstrate deep engagement. If, for example, the tasks or instructional activities focused on memorizing and applying algebraic procedures, such as solving an equation, there was little opportunity for students to make a deep mathematical connection, provide a deep justification, or engage in deep problem solving. If, however, the task or instructional activities emphasized the relationship between the solution to an equation and a real-world context, a graph, or a table, students had more opportunity to identify a deep connection, create a deep justification, or engage in deep problem solving. Exhibit 10 shows examples of the tasks our teachers used to focus on math relationships and promote deep engagement with the content.

Exhibit 10. Tasks that Focus on Math Relationships for Connect, Justify, and Solve

Task Type

Task to promote deep **connections**

(Developed by a BMTN teacher)

In the "Saving for a Bike" task Jenny started with \$50 in her savings account and saved \$5 per week. You and your classmates developed the following rule to represent how much she saved:

$y = 5x + 50$

a. How is the equation $y = 5x + 50$ related to the linear function $f(x) = 5x + 50$?

b. When asked how much money Jenny would save after 8 weeks, you and your classmates decided to do the following: $y = 5(8) + 50$

- How is this equation related to what you know about inputs and outputs for functions?

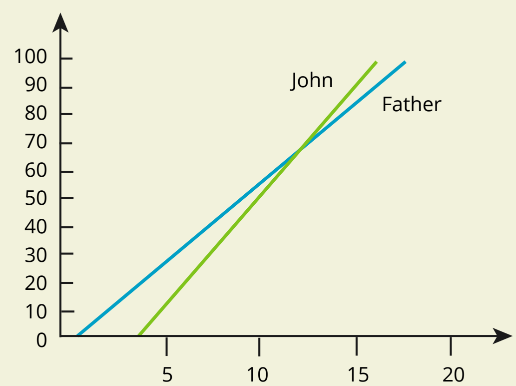
c. When asked how long it would take for Jenny to save \$185, you and your classmates decided to do the following: $185 = 5x + 50$

- How is this equation related to what you know about inputs and outputs?

Task to promote deep **justifications**

(Edited from Better Lesson[13])

John and his father ran a 100 meter race. John started the race 3 seconds after his father. The graph below shows how far the two ran over time.



Answer the following questions as completely as you can:

1. *Who won the race?*

   ____________________________________*won the race.*

2. *I know this because*________________________________

   ____________________________________-____________.

Task to promote deep **problem solving**

(Edited from Illustrative Mathematics)

The table below shows two coordinate pairs (x, y) that satisfy the equation $y = mx + b$ for some numbers m and b.

x	y
2	$y1$
5	$y2$

I.

If $\boldsymbol{m} = 7$, determine possible values for $y1$ and $y2$. Explain your choices.

II.

Find another pair of y-values that could work for $\boldsymbol{m} = 7$. Explain why they would work. How do these y-values compare to the first pair you found for $\boldsymbol{m} = 7$?

DATA SOURCE: BMTN change idea summaries, 2017–18 school year.

When they wanted to assess the extent to which students were deeply engaging with the content as they worked with math relationships, our teachers learned they needed to use very specific questions. For example, teachers learned that asking, "What connections did you make?" or "How do you solve that?" does not necessarily elicit deep responses from students, even if the students are deeply engaged. Instead, BMTN teachers learned that they need to explicitly address the mathematical ideas in their questions to assess the depth of student engagement. Exhibit 11 shows sample questions they used for this purpose.

Exhibit 11. Questions to Elicit and Assess Deep Engagement with Algebra Content

- What connections do you see between the shapes puzzles and systems of equations?
- How does recognizing the pattern help you determine the value of the negative exponents?
- What is the new idea we discussed today? How is it connected to what you already know?
- Student A got one answer and student B got another answer. Who is correct? Explain and support your answer with evidence.
- How do you know your answer is correct?
- What information is important to solving the task? Why?
- What solution path will you take to solve the problem? Why?

DATA SOURCE: BMTN change idea summaries, 2017–18 school year.

To maximize student engagement with the tasks and explicit questions they were using to support deep engagement, our teachers found that they needed to provide time for students to work individually before working with other students. This "individual think time" offered the opportunity for *all* students to engage with the content before they moved to small- or whole-group discussion and heard how others were thinking. Teachers also found that the amount time needed for individual processing varied depending on the type of instructional routine and complexity of the task or question.

Even when they implemented instructional tasks that focused on math relationships, used questions that targeted specific math content to assess deep engagement, and provided students with "individual think time," our teachers found that they need to do more to support students in understanding what constitutes deep engagement. For students to demonstrate deep engagement, they needed to know what deep engagement looks like. Specifically, students needed to see examples of deep connections, deep justifications, and deep problem-solving processes and they needed opportunities to practice demonstrating deep engagement with feedback. Exhibit 12 shows some of the approaches teachers used to provide these opportunities.

Exhibit 12. Opportunities to Understand and Build Skill in Demonstrating Deep Engagement

<table>
<tr><th>Strategy</th><th>Description</th></tr>
<tr><td>Critique Examples</td><td>Provide samples of connections, justifications and of problem solving processes.
Ask students to critique the depth of the work.
As a group identify characteristics and/or introduce a rubric to evaluate deep engagement.</td></tr>
<tr><td>Sentence Frames</td><td>Provide a series of sentence frames to help students demonstrate deep engagement. For example: "I think the answer is ________ because _______."</td></tr>
<tr><td>Graphic Organizers</td><td>Provide a graphic organizer to support writing. For example:
<table>
<tr><td colspan="3">CLAIM (your answer to the question prompt)</td></tr>
<tr><td>Subclaim
(reasons your claim is true)</td><td>Evidence
(comes from the math you did and math concepts)</td><td>Reasoning/Justification
(explaining your evidence and connecting it back to your claim)</td></tr>
<tr><td>Possible sentence starters:
• "One reason that supports my claim is…"
• "This is true because_____"</td><td>Possible sentence starters:
• "When looking at______"
• "The evidence to support this comes from_____"</td><td>Possible sentence starters:
• "This shows that…"
• "This proves that…"</td></tr>
</table></td></tr>
<tr><td>Ordering Statements</td><td>Provide a series of sentences and ask students to order the statements so that they clearly demonstrate deep engagement.</td></tr>
<tr><td>Practice with Feedback</td><td>Collect student responses.
Use a rubric to provide feedback to improve the depth of student responses.
Students use the feedback to create new responses.</td></tr>
</table>

DATA SOURCE: BMTN teacher change idea summaries, 2017–18 school year.

Finally, our teachers learned that to design and implement instruction that promotes deep student engagement, they needed to have a deep understanding of the math content for themselves. For example, to pick a task that is ripe for making deep connections, providing a deep justification, or engaging in deep problem solving, teachers needed to know what math relationships the task should target and how one might explain those relationships. To support teachers in deepening their understanding of math relationships, we organized a collection of book study groups that read and discussed one of two books from the National Council of Teachers of Mathematics' *Essential Understandings* series.[14] Each book in the series focuses on the "big ideas" and related "essential understandings" that are central to a math topic recognized as challenging to teach and learn. A majority of BMTN teachers (24 of the 41) elected to join a study group. Each teacher in the group took turns leading the group. We did not attend the sessions, but we did ask teachers to record and document activity within those session, Participating teachers reported high levels of satisfaction with the content and structure. Exhibit 13 provides an overview of the book study group activity.

Exhibit 13. BMTN Book Study Groups

Impetus: As teachers delved further into their PDSA testing, they decided that to promote student understanding of mathematical relationships, they needed to take some time to solidify their own understanding of some of the major concepts in algebra. They showed interest in forming small book study groups after a whole network meeting activity in December 2017.

Participants: A total of 24 of the 41 BMTN teachers participated in the voluntary book study groups. Participants included new and returning network teachers, and each group had three or four members.

Topics and Structure: The study groups were formed based on their availability to meet and their interest in one of two books: (1) *Functions*, which was targeted to students in grades 9–12, and (2) *Expressions, Equations, and Functions*, which was targeted to students in grades 6–8.

We provided each group with a suggested structure, though groups had leeway in how much they decided to read and how often they met. Groups met virtually 5–7 times, with each meeting lasting about one hour. We encouraged groups to use the following **discussion questions** for each meeting:

1. What are your initial reactions? Did you learn anything new—or think about something familiar differently—based on what you read? If so, what was new?
2. Did you have any questions related to the Reflect activities you completed? If so, what were they?
3. To what extent did the content you read about align with how this content is presented in your curriculum/textbook?
4. Are there any lingering questions?

We also initially assigned each group a meeting **facilitator** and a **note taker**. The facilitator made sure that the discussion questions were posed and that each person had the opportunity to respond. The note taker captured a high-level overview of what was discussed and documented each meeting in a shared group folder. We encouraged groups to take turns playing each of these roles.

Teacher Perceptions: Based on informal interviews and a review of archival information from the meetings (e.g., meeting notes, recordings of the virtual meetings), teachers actively participated in the study groups and found the meetings valuable. We plan to offer study groups again during the 2018–19 school year.

Lessons Learned Related to Network Structures to Support Spread

As we increased the size of our network and moved into the second year of implementation (2017–18), we began to focus on spreading (a) the refined student-centered instructional routines that were developed through PDSA testing in the first year and (b) structures for supporting continued testing of those instructional routines inside and outside of the network. Specifically, we shared the refined routines with new and returning members in the network, encouraged teachers to test those routines or a version of them, and put structures in place to support new members in learning about the PDSA process. In addition, we shared the refined routines with instructional leaders outside of the network and worked closely with one leader to facilitate a professional learning community (PLC) of teachers in her district. The PLC focused on testing one of those routines and learning about improvement science. Through this work, we learned the following:

- To promote implementation and continued refinement of instructional routines in new contexts, provide the “refined” routine as well as a list of “key learnings” about how to support deep student engagement that emerged during the testing process;
- To support spread within the network, provide summaries of the routines that were tested and refined the previous year and place new and returning members in the same testing groups; and
- To support spread outside of the network, provide a routine to test and guide teachers through the PDSA process with that routine.

At the end of the first year of the network (2016–17), each BMTN teacher created a “change idea summary,” which synthesized findings from a full year of PDSA testing. The change idea summaries gave an overview of the problem they were trying to solve, described the change idea they tested, provided a detailed outline of the “refined” routine they recommended after repeated testing, included the data they collected that showed evidence of promise, and offered advice for implementing the refined routine. These change idea summaries were intended to be a mechanism for spreading the refined routine to other teachers inside and outside of the network.

As we shared the change idea summaries with others, we learned that teachers were not necessarily ready to implement the refined routine as described in the change idea summary. Teachers teach in different contexts and use different instructional approaches. Some teachers work with students who have experienced student-centered instruction throughout their educational careers. Others work with students who are used to lecture-style instruction. Some teachers already use student-centered instructional approaches in their classrooms. Others are just starting to use those approaches. Each refined routine was the result of a full year of testing in a specific context by a teacher who had a specific instructional approach. In addition to teaching in a potentially different context with a potentially different instructional approach, teachers trying the routine for the first time have not spent a full year refining the routine to match their students. This makes it difficult for teachers to implement the refined routine as described.

Given these challenges, we found it helpful to provide teachers with a list of “key learnings” as well as the change idea summary that included the refined routine. These key learnings highlight important findings that emerged and contributed to the refinement of the routine over the year of testing. For example, as described in the previous section, teachers learned that it is important to provide individual think time on a new task before moving to group work. This could be listed as a key learning on teachers' change idea summaries. If teachers are not ready to implement the refined routine as described, they can implement a modified version that attends to the key learnings but that can be more reasonably implemented in their context, given their background. Exhibit 14 shows an example.

Exhibit 14. Excerpt from a Change Idea Summary that Includes Key Learnings

Problem:
Justification does not come naturally to students and they are rarely asked to do so before coming into our classrooms. I have found that students often want to get to the solution, but do not necessarily work to understand beyond the procedure to solve or the reasonableness of the solution.

Change Idea:
I want to improve my students' ability to justify their own learning and understanding of material by presenting problems that will allow student disagreement or a need to prove that the result is rational. I am going to incorporate more unfamiliar problems that have multiple entry points into my instruction and provide opportunities for students to communicate and justify their thought process and approach.

Key Learnings:
- It is important to give students individual thinks time before they work in small groups.
- Students worked best either with a partner or a group of three.
- Students need to know the expectations and what a good justification is to be able to give meaningful justification.
- Not all tasks have to have real world applications to qualify as a justification task.

Final Routine:
1. Give the students a problem or task with multiple entry points that incorporate the students' new and old math knowledge.
2. Have the students read through the problem and give them private reasoning time before moving to group work.
3. (If the students are struggling I ask them to write down questions that they have.) Give anywhere between 5 to 10 minutes.
4. I look at how engaged the class is with the task to determine the time.
5. Allow students to work in small groups (arrange them) or with their table partner. Give students one minute each to share their thoughts or questions on the topic. Give the group two more minutes to see if they can answer or address their new learning.
6. If students still have questions they may write them on a post-it and put them in the parking lot of questions for the class or teacher to answer. (Not all questions in the parking lot have to be answered, but some may need to be answered for students to continue with their work.)
7. Give students 5 to 10 minutes to continue the tasks if they haven't finished. Make sure you give time to students to justify their solution.

DATA SOURCE: BMTN change idea summaries, 2017–18 school year.

Within the network, we supported new members in implementing modified versions of the refined routines or new routines altogether by providing opportunities to work with returning members in PDSA testing groups. We learned that by including both new and returning members in the same testing groups, new members learned about the PDSA process—including how to measure improvement—and gathered ideas for providing students opportunities to deeply engage with content. As hub leaders, we still attended the PDSA testing meetings and served as coaches. As we facilitated the meetings, we found that the returning members' contributions enhanced the learning of the new members.

Outside the network, we used the key learnings to modify two refined routines that could most easily be implemented in a high school math classroom regardless of context or instructional approach and shared them with the ten instructional leaders who were affiliated with the network. We encouraged the instructional leaders to share the routines with other teachers and provide feedback regarding how things went when they implemented the routines. One instructional leader shared the routine with a few teachers and expressed interest in forming a PLC in her district focused on implementing the routine and using PDSA cycles to improve it. We partnered with her and organized a series of PLC sessions, with each session addressing a step in the PDSA cycle, using the modified routine. In other words, teachers learned about PDSA testing and completed the **Plan** step in the first session, tested and collected data on the routine in their classrooms, completed the **Do** and **Study** steps in the next session, continued testing in their classroom, and discussed next steps in the final session. This approach of providing a modified routine that was based on the refined routine and associated key learnings and using that routine to learn about the steps of the PDSA process worked well for spreading the routine and the PDSA process to others. Exhibit 15 provides more information on the PLC work.

Exhibit 15. PLC Work with Teachers Outside of the Network

Impetus: We were interested in learning how to spread refined routines and the PDSA process to teachers outside of the network. One instructional leader was interesting in working with middle and high school teachers to implement and continue to improve instructional routines using PDSA testing.

Participants: One instructional leader, who is the department chair at a high school in New England; four math teachers at that high school; six math teachers from the feeder middle school.

Topics and Structure: We organized a series of three PLC sessions, each led by a BMTN hub member, with work periods in between each session. During each work period, teachers tested a routine that was developed by one of the teachers in the BMTN.

PLC Session #1	• Learn about the BMTN, including the problem we are solving, our aim, and the driver diagram • Learn how to use PDSA testing to make improvements • Learn about a refined instructional routine that was developed by one of the BMTN members
Work Period #1	• Implement the instructional routine and collect data (Plan, Do)
PLC Session #2	• Analyze the data using a BMTN rubric and use the analysis to decide what modifications to make (Study, Act) • Learn about a second refined routine that was developed by a BMTN member
Work Period #2	• Test and refine one of the two refined routines using the PDSA process
PLC Session #3	• Share learning from the testing and consider next steps

Teacher Perceptions: Teachers enjoyed having the opportunity to discuss instruction. They felt the PDSA process provided them an opportunity to look more closely at instruction and student engagement. Specifically, they learned to look beyond a student's answer to determine whether that student had deeply engaged with the content. All teachers were interested in continuing the next school year.

Where We Are Headed Next

As we reflect on the lessons learned from our network's second year, we have identified areas for continued growth and for new growth. We plan to continue to leverage the experience and expertise of our returners and the support structures for small-group and whole-network learning. We plan to reach new teachers through PLC meetings similar to the model we piloted in 2017–18 and described in Exhibit 15. As we expand, we anticipate learning more about what student-centered instruction looks like, how to enact it, and how to spread promising instructional routines. We also anticipate that our growth will provide additional opportunities for teacher leadership.

More specifically, we view **teacher leadership** as critical to the success of the network, but also important to the profession overall. Our returning teachers will assume several types of leadership roles in the coming school year. Several returners will facilitate small-group PDSA testing meetings, after receiving an initial training with ongoing support from the hub. Others will be leading PLC meetings at their schools with other math teachers, following the model we piloted this year. Others plan to make formal presentations to school and district leaders about how improvement science and instruction-oriented improvement networks function. And we expect more of our returners to continue to present their BMTN work at state, regional, and national conferences.

We expect to continue to learn how the **spread of knowledge** best occurs inside and outside the network. This report describes some initial learnings about spread, but as we reach more teachers, we expect to learn a great deal more. This knowledge will be critical to supporting our goal of deeply engaging an increasing number of students in algebra.

Finally, as we share our work within the broader (and growing) community of improvement networks, we are mindful that a limited number of networks are focused primarily on **improving instruction**. As we work closely with teachers on testing and refining routines within complex classroom environments, we hope to contribute useful information about such networks in the improvement science community. We also think that our work might support other strands of work that need further research and development, including student-centered instruction, teacher professional development, teacher leadership, and research-practice partnerships.

[1] A report describing our first year of implementation can be found here: https://www.nmefoundation.org/resources/assessment/the-better-math-teaching-network-lessons-learned.

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[7] National Center for Education Statistics (20180; OESE, 2017

[8] President's Council of Advisors on Science and Technology. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Washington, DC: Office of the President. Retrieved from https://files.eric.ed.gov/fulltext/ED541511.pdf.

[9] We estimated that BMTN teachers would work with 2,500 – 3,000 students over the three-year project and selected roughly 2,000 as a realistic target for deep engagement. We added 19 students to this estimate to match the year of the project (2019) and concretely link the target number of students with the project timeline.

[10] Bryk et al., 2015. Langley, G.J., Moen, R.D., Nolan, K.M., Nolan, T.W., Norman, C.L., & Provost, L.P. (2009). The improvement guide: A practical approach to enhancing organizational performance, 2nd ed. Jossey-Bass Publishers: San Francisco, CA.

[11] Items on the survey were informed by the Survey of Chicago Public Schools from the Consortium on Chicago School Research at the University of Chicago.

[12] LeMahieu, P.G., Grunow, A., Baker, L., Nordstrum, L, & Gomez, L.M. (2017). Networked improvement communities: The discipline of improvement science meets the power of networks. Quality Assurance in Education, 25(1), 5-25.

[13] See https://betterlesson.com/.

[14] See https://www.nctm.org/store/all-products/series/?cp=1&tx=217.

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