The Better Math Teaching Network

Lessons Learned from Year 3

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REPORT SUMMARY

The Better Math Teaching Network (BMTN) is a networked improvement community (NIC) 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 third year of implementation occurred during the 2018–19 school year. Key findings include:

- **High rates of teacher participation in intensive program.** Similar to the first two BMTN cohorts, teachers in the third cohort devoted about 100 hours to individual, small group, and whole group network activities, both in-person and virtually.
- **The network met its aim of increasing deep student engagement.** The BMTN set out to increase the number of students deeply engaged in algebra by 2,019 by the year 2019. A cumulative total of 2,074 students reported deep engagement in spring 2019, exceeding the aim.
- **Teachers continued to learn about student-centered instruction.** BMTN continued to test and refine student-centered instructional routines and learned more about specific approaches for promoting deep student engagement in the math processes of making connections, creating justifications, and problem solving.
- **Network-created resources can support spread of student-centered instructional routines and improvement processes.** The network created rubrics, training videos, and a task library to support network teachers in learning about and engaging in continuous improvement of instruction. These resources helped to spread learning to teachers within and outside of the network.

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Network Overview

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. We launched the network during the 2016-17 school year and have grown each year since. This report describes lessons learned from the 2018-19 school year, our third full year as a network.

Improving Instruction Through Improvement Science

Fifty-two high school algebra teachers form the core of our improvement community. They develop, test, refine, and share instructional routines that are designed to foster deep student engagement in algebra. These teachers represent every state in New England and primarily work in urban and rural schools serving high proportions of economically disadvantaged students. The network also includes 20 secondary math teachers, and two instructional leaders, who participate in BMTN-led improvement communities from two school districts in Rhode Island. Their work focuses on learning the tools of improvement science and testing BMTN-developed instructional routines in their schools and classrooms. The network's leadership hub consists of five members from the American Institutes for Research (AIR) and WestEd. Two researchers with expertise in math education and improvement science lead the hub, and they are supported by a math education researcher, a project manager, and a communications specialist.

Our network uses principles from improvement science to structure our work. This approach has been used for decades to drive improvements in health care and other industries, but it is somewhat new to education.[1] The approach involves collaborative work using quick-cycle testing to refine instructional routines while paying attention to variation in implementation and results. As new learnings are established, promising strategies and novel ideas are shared throughout the network, stimulating further improvements and implementation in other contexts. To facilitate collaboration and sharing, the BMTN provides the core 52 teachers with structured opportunities to meet in-person, as a full group, and virtually, in smaller groups. These structured activities total roughly 100 hours per academic year per teacher, though many teachers report spending additional time meeting with other teachers informally. Educators in BMTN-led learning communities spend roughly 12 hours per year, through four, 2.5-hour meetings at their schools with action periods in between meetings.

Defining Student-Centered Instruction

In 2014, BMTN hub leaders and other colleagues published a mixed-methods study of student-centered math instruction.[2] The study found a positive association between students' problem-solving skills and the strength of student-centered instruction in their classrooms. The study also produced a framework for classifying instructional approaches as strongly student centered. For example, strongly student-centered instruction encourages students to communicate their thinking and critique the reasoning of others. We used this framework, which built upon prior math education research and expert recommendations,[3] to inform initial discussions about the types of instructional improvement work we wanted to carry out as a network. Through highly collaborative discussions and ongoing refinements, our network decided to focus on deepening student engagement in three mathematical processes: *connect*, *justify*, and *solve*. More specifically:

- **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.

As a network, we test and refine instructional routines that support student engagement within each of these processes and share our learnings with each other. We focus the testing primarily on algebra classrooms because it is a well-documented "gatekeeper" to advanced math and science high school coursework, and subsequent college and STEM-related career opportunities.[4]

Network Aim and Driver Diagram

NICs define and pursue a specific aim to which all improvement efforts are directed. During the first year, we created an aim statement that specified the number of students we hoped to deeply engage in the network's focal math processes:

AIM STATEMENT

By 2019, the BMTN aims to increase the number of New England students who connect, justify, and solve with depth by 2,019.

NICs also construct a working theory of improvement that describes the key levers that are most likely to drive improvement toward reaching the aim. A driver diagram is a visual tool used to organize improvement levers and associated change ideas to be tested.[5] The tool also provides network members with a common language to guide their collaborative, aligned efforts. The BMTN driver diagram, presented in Exhibit 1, has a primary driver of math instruction. The network is focused on changing math instruction so that it provides increased opportunities for students to *connect*, *justify*, and *solve* with depth. Teachers can provide these opportunities by choosing tasks that support deep engagement and by shifting the academic responsibility from the teacher to students. Instructional routines that have these features are defined to be student-centered. We also hypothesize that student-centered instructional routines may differ depending on whether the math content is new for students. Thus, our secondary driver distinguishes new from previously introduced lesson content. The specific change ideas, or instructional routines, that teachers develop, test, refine, and share are aligned to both the primary and secondary drivers. These instructional routines are where improvement theory meets practice, providing data for continuous improvement to help the network reach its aim.

Exhibit 1. BMTN Driver Diagram

AIM STATEMENT

Deep Student Engagement in Algebra

2,019 in 2019:
By 2019, the number of students who **CONNECT**, **JUSTIFY**, and **SOLVE** with depth in algebra will increase by 2,019.

CONNECT: Make connections among mathematical algorithms, 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 math problems that extend beyond rote application of algorithm.

PRIMARY DRIVER
WHAT?

Mathematics Instruction

Mathematical instruction provides ongoing opportunities for all students to **CONNECT**, **JUSTIFY**, and **SOLVE** in algebra through the **choice of task/activity** and by **shifting the academic responsibility to students.**

Instruction is **student-centered**

SECONDARY DRIVERS
WHERE?

Instructional Routines to Introduce New Material

Instructional Routines to Practice/Reinforce Previously Introduced Material

CHANGE IDEAS
HOW?

Remainder of Report

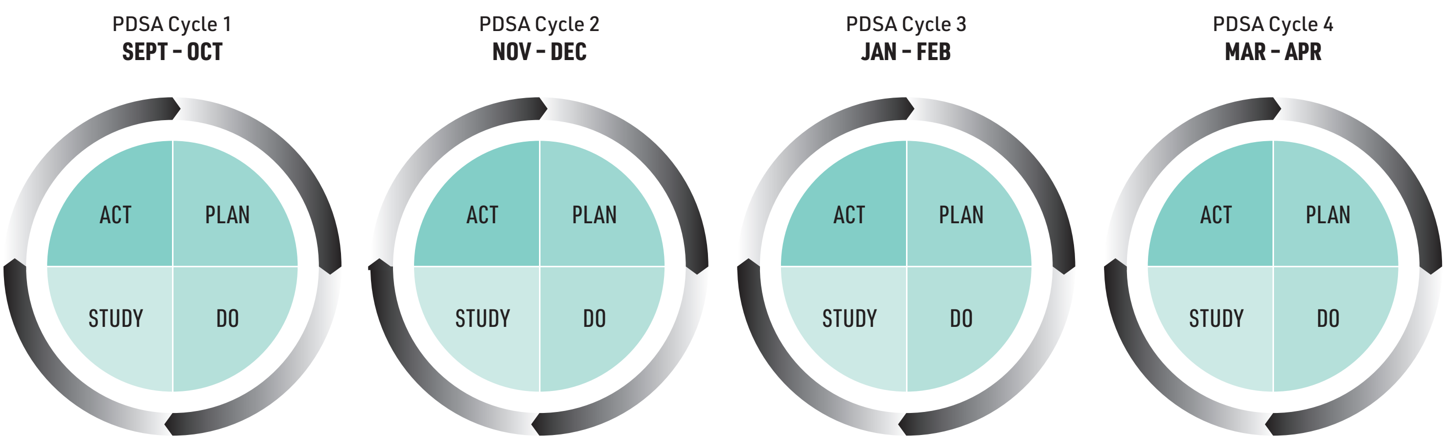
The rest of this report is organized by four main sections. In the next section, we describe the process teachers used to test and refine their student-centered instructional routines, provide examples of those routines, and summarize lessons learned. The following section illustrates how the network supported the spread of promising change ideas inside and outside the network and describes key lessons learned. The third section presents the data the network collects from teachers and students to track progress towards the aim and summarizes our progress to date. The final section identifies next steps for the 2019-20 school year.

Testing Student-Centered Instructional Routines

Process for Testing Change Ideas

One of the key processes used in improvement science is *Plan-Do-Study-Act (PDSA)* trials. BMTN teachers use PDSA trials to test and refine promising change ideas, or instructional routines. First, teachers identify an area of focus for their improvement work (*connect, justify,* or *solve*) and select a change idea that holds promise for improving student engagement in their chosen area of focus. Next, they create a *Plan* that describes how the change idea will be implemented, the supporting data to be collected, and predictions for what the data might reveal. Then, in *Do*, they implement the planned routine, collect data, and note immediate reactions related to implementation. In the *Study* phase, teachers analyze the implementation data more carefully, comparing the results with their predictions and beginning to formulate what to try next. During the final phase of the trial, *Act*, teachers decide whether to adopt the current routine, adapt it, or abandon it. Teachers complete several PDSA trials individually before meeting with a small group to discuss what they learned with other teachers. At the end of the small-group meeting, teachers look across the data collected in each trial and decide what they want to test in the next series of trials. The end of the meeting marks the end of one cycle of PDSA testing. The next set of trials begins a new PDSA cycle. As illustrated in Exhibit 2, BMTN teachers complete four PDSA cycles per year, roughly eight weeks per cycle. Teachers typically complete two or more trials per cycle.

Exhibit 2: BMTN PDSA Testing Timeframe



Instructional Routines Tested and Refined in 2018-19

In previous years, teachers learned the value of using tasks that emphasize math relationships, rather than rote procedures; using and removing scaffolds to support deep engagement; providing students with individual think time before sharing their thinking with others; and offering opportunities for students to see examples of, practice, and receive feedback on their attempt at deep engagement. Teachers also learned that in order to emphasize and assess deep student engagement, they needed to have a deep understanding of the math content for themselves and use questions that explicitly address math relationships with their students.* In this third year, teachers tested routines that incorporated these elements for each of the three math processes: *connect*, *justify*, and *solve*. Overall, about half of the instructional routines that teachers tested this year focused on solve and half focused on *connect* or *justify*—roughly one-quarter each.

As shown in Exhibit 3, 12 teachers tested routines designed to support students in making deep connections; four of those routines focused on the introduction of new material, seven focused on practicing previously learned material, and one focused on both. Each of the routines included individual and small-group work, scaffolding, or feedback on the depth of connection.

Exhibit 3. Instructional Routines Focused on Connect, 2018-19 BMTN Teachers

	Secondary Driver	
Instructional Routine: Connect	**Intro**	**Practice**
Making mathematical connections through individual and small-group work		✓
Using mid- and end-of-unit exit tickets with feedback to support deep connections		✓
Connecting big ideas in mathematics to abstract tasks with individual warm-up and whole-class discussion		✓
Using guided questions to support deep connections		✓
Using scaffolded writing tasks to promote connections		✓
Making connections using guided questions and feedback	✓	
Using guided questions, individual and small-group work to support connections	✓	
Using exit tickets to determine scaffolding levels for new material and connections	✓	
Incorporating concept maps, individual think time, and small-group work to make connections to previously learned material		✓
Using an individual warm up and small-group discussion to facilitate development of new connections	✓	
Deeper connections using letter writing and video messaging with feedback		✓
Using individual, small-group, and whole-group work to facilitate connections	✓	✓

DATA SOURCE: BMTN teacher change idea summaries, 2018-19 school year.

* For more detail on these routines, please see BMTN Lessons Learned reports from the first and second year of implementation – https://www.nmefoundation.org/resources/better-math-teaching-network-year-2-resources/

Twelve teachers focused on improving the depth of students' justifications. Exhibit 4 shows descriptions of the routines these teachers tested. All but two of the teachers tested routines that provided opportunities to practice previously introduced material. Each of the routines included opportunities for students to reflect on their own or others' justifications through small-group work, whole-group discussion, or by reviewing individualized feedback from the teacher. More detail on these routines can also be found on our website (www.bettermathteachingnetwork.org).

Exhibit 4. Instructional Routines Focused on Justify, 2018-19 BMTN Teachers

	Secondary Driver	
Instructional Routine: Justify	**Intro**	**Practice**
Strengthening justifications through peer feedback		✓
Supporting deep justifications through scaffolded tasks		✓
Supporting deep justifications by facilitating whole-class critique of anonymous student justifications		✓
Using exit tickets and time to work with others to promote deep justifications (2 teachers)	✓	
Supporting justifications by asking peers to present and justify or critique others' solutions		✓
Incorporating justifications into the individual warm-up and small-group discussions		✓
Supporting justifications by asking students to pair a student-produced justification with the teacher feedback	✓	
Using Google forms with feedback to promote justifications on homework		✓
Using debating, along with individual think time, to foster deep justifications		✓
Scaffolding student discourse using claim, evidence, reasoning (CER) writing		✓
Using individual work followed by classroom presentations to justify and compare solution methods		✓

DATA SOURCE: BMTN teacher change idea summaries, 2018-19 school year.

Finally, 23 teachers tested routines designed to support students in problem solving with depth. As shown in Exhibit 5, five teachers tested routines focused on introducing new material, 11 tested routines focused on practicing previously learned material, and six tested routines targeting both. The routines emphasized use of scaffolds to support students in each step of the problem-solving process.

Exhibit 5. Instructional Routines Focused on Solve, 2018-19 BMTN Teachers

	Secondary Driver	
Instructional Routine: Solve	**Intro**	**Practice**
Using prompts with structured math talk to facilitate problem solving	✓	
Using problem solving prompts, individual think time, and paired discussions to support problem solving	✓	✓
Using prompts and a list of suggestions to use when stuck in the problem-solving process		✓
Annotate; Try Something; Revise; Decide – Scaffolds to support independent solving	✓	
Using a quiz correction form to promote metacognition		✓
Solving non-routine problems in algebra using a solution method template	✓	
Scaffolding the process of problem solving	✓	✓
Using public records and small-group work to foster independence with solving non-routine problems		✓
Using structured student discourse strategies to increase student engagement with challenging problems	✓	✓
Providing feedback and a template to correct work to promote problem solving with depth		✓
Student choice and whole-class discussion of solutions to warm-up problems		✓
Comparing solution methods to promote deep problem solving (2 teachers)		✓
Task-based instruction with a problem-solving template to introduce new material	✓	
Analyzing errors to develop problem-solving skills		✓
Rough draft thinking to support deep problem solving	✓	✓
Exit tickets with feedback to support problem solving		✓
Using prompts to support independent think time when solving challenging problems	✓	
Assigning roles and providing prompts to support small-group problem solving	✓	✓
Using common student errors and group corrections to facilitate problem solving		✓
Using scaffolding to support problem solving	✓	✓
Using feedback and multiple attempts to support problem solving		✓
Using roles with a template to support problem-solving during group work		✓

DATA SOURCE: BMTN teacher change idea summaries, 2018-19 school year.

More detail on each of the routines presented in this section and those tested in previous years can be found on our website (www.bettermathteaching.org). Entries for this year's routines are also accompanied by short audio-recordings of teachers describing the routine and what they learned about it through testing.

Key Learnings

As teachers shared and discussed what they learned from their testing, one theme for each of the three focal math processes emerged:

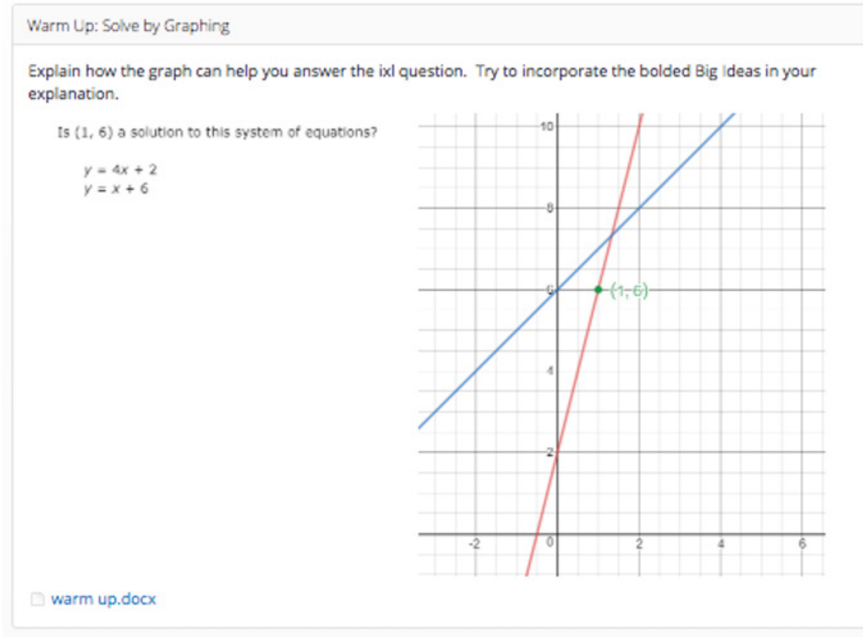
- **CONNECT.** It takes time for students to develop deep connections of abstract concepts. Instructional activities should provide opportunities for students to first look for connections in concrete examples before moving to more abstract generalizations.
- **JUSTIFY.** Students cannot develop deep justifications unless they first have a deep understanding of the concepts included in the justification. Instructional activities that ask students to justify their thinking should focus on content students understand.
- **SOLVE.** Students need support to develop deep problem-solving skills. Instructional activities should use problems that can be solved with multiple methods and teachers should offer problem-solving prompts to guide students' problem-solving processes.

These themes provide more insight into instruction that supports student engagement with *connect*, *justify*, and solve than had been gleaned in prior years. We elaborate on each in turn.

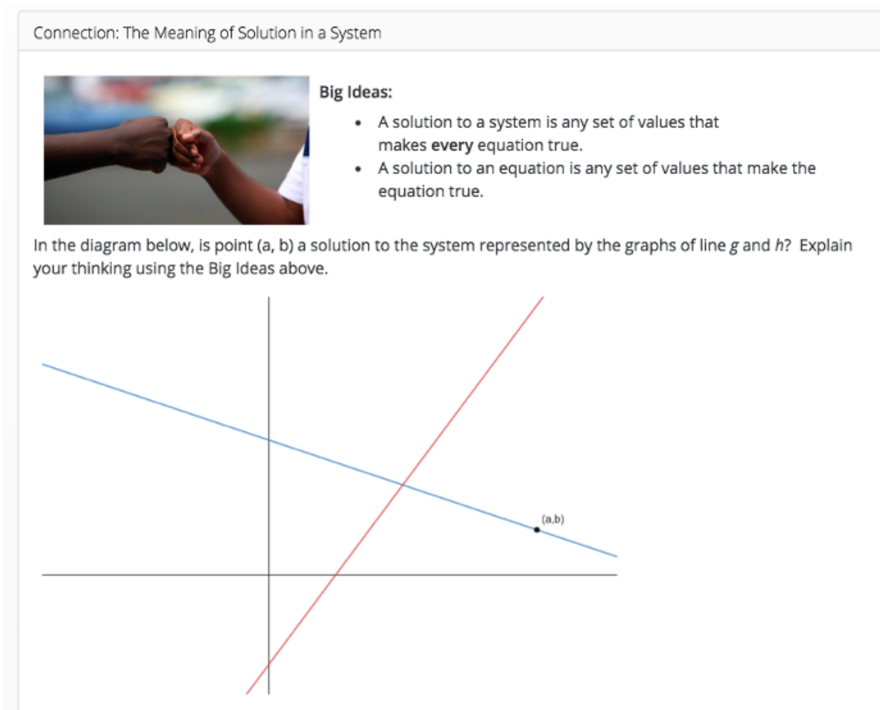
Developing deep connections. Our network defines deep connections as the understanding of the relationship between two math concepts, a math procedure and the concepts that support that procedure, or two procedures. As teachers tested routines to support such depth, they learned that students first needed multiple opportunities to make connections with concrete examples. Then, over time, students could begin to generalize those connections to more abstract concepts. Exhibit 6 shows an example of a concrete and abstract task that a BMTN teacher used to support students in making connections among equations, graphs, and solutions. The concrete example requires students to reason about the connections among graphs, equations, and solutions using specific equations and a given point: (1,6). In the abstract example, students must generalize their understanding of the connections among equations, graphs, and solutions to a situation in which all numbers have been removed.

Exhibit 6. Sample Task: Moving from Concrete Examples to Abstract Generalizations

Concrete Example to Support Students in Making Connections Among Equations, Graphs, and Solutions



Abstract Example to Support Students in Generalizing Connections Among Equations, Graphs, and Solutions



DATA SOURCE: BMTN teacher PDSA testing records, 2018-19 school year.

Producing deep justifications. Our network defines deep justifications as those that are clear, rely on math relationships and not rote procedures, and have no gaps in reasoning. As teachers tested instructional routines designed to support students in producing justifications with these features, they learned that students were most successful when the justification activities were presented after, and not during, work to complete a task or solve a problem. By justifying work already completed, students were better able to focus on the features of a deep justification, including its reliance on math relationships. Exhibit 7 shows a sample task that one teacher used to support justifications. The task was presented as a warm-up, addressing previously introduced material. They were asked to solve the problem, then write a justification.

Exhibit 7. Sample Task: Justification Prompt Used in a Warm-Up with Previously Introduced Material

Nina made two investments. Investment A has a value of $50 at the end of the first year and increases by 8% per year. Investment B has a value of $60, at the end of the first year and increases by $3 per year.

Nina checks the value of her investments once a year, at the end of the year. Will investment A's value ever exceed investment B's value?

Explain your reasoning and JUSTIFY your answer using complete sentences and appropriate mathematical vocabulary.

DATA SOURCE: BMTN teacher PDSA testing records, 2018-19 school year.

Engaging in deep problem-solving. Our network defines deep problem solving as students actively making sense of what the problem is asking, selecting reasonable solution approaches, monitoring their work and changing approaches as needed, and making sense of the final answer. In their testing, teachers learned that students more effectively developed deep problem-solving skills when they worked with problems that could be solved in multiple ways, enabling them to select an approach that made sense to them. To further support students in reasoning about their approaches and solutions in the context of the problem, teachers should provide targeted problem-solving prompts at different phases in the problem-solving process. Exhibit 8 shows some example problem solving prompts that BMTN teachers used in their testing.

Exhibit 8. Sample Prompts: Supporting Deep Problem Solving

Pre-Thinking Questions
1. What important information are you given? You can write it below, or underline it in the problem.
2. In your own words, what is the goal of the task?
3. Describe what your solution will look like (i.e. Will it be a small number? Will it be a yes or a no? Will it be a diagram?, etc.). Be as specific as possible!
4. What are your clarifying questions? (Questions about the provided information.)
5. What is your initial idea about how you might solve the problem? Check off one method and then explain how you plan to use this method. ☐ Act it Out ☐ Draw a Picture ☐ Look for a Pattern ☐ Guess, Check, & Improve ☐ Make a List ☐ Try a Simpler Case ☐ Work Backwards ☐ Other: ______________
Reflection Questions
6. State your solution. Make sure you responded to the goal of the task.
7. Explain how you arrived at your solution. What lead you to the answer in question 6? This should be a step-by-step explanation of your work.
8. Explain how you checked your answer. Show work for how you checked your answer.

Spreading Instructional Routines and Improvement Science Processes

Another strand of our work focuses on facilitating the spread of promising routines and knowledge of improvement science processes. Building on what we have learned in prior years, we continue to implement effective strategies and try new approaches to spread knowledge within the network and outside of the network through school- and district-based teams.

Activities Designed to Promote Spread Inside and Outside the Network

Strategies that have been effective in promoting spread in the past include pairing new teachers with returning teachers; encouraging teachers to test change ideas found in *Change Idea Summary* books produced by the network each year; providing opportunities for teachers to share their learning in whole-network meetings throughout the school year; and working with two instructional leaders to support external, school-based PLCs focused on testing change ideas developed by network members. This year, we added three new ways to promote spread. First, we developed PDSA training videos with interview and classroom footage from a BMTN teacher. Second, we finalized common rubrics for assessing depth of engagement to help teachers in PDSA testing. Third, we encouraged network teachers to take on leadership roles to spread the work inside and outside the network. Each of these new supports facilitated the spread of change ideas and use of the PDSA processes to study instructional routines and depth of engagement.

PDSA training videos. During the second year of the network, we worked with an experienced BMTN teacher to develop a series of training videos about how to use PDSA cycles to test and refine instructional routines. The videos include a series of testimonials in which the teacher describes her approach to the *Plan*, *Do*, *Study*, and *Act* phases of a PDSA cycle. The videos also include footage from her classroom to show what happened when she implemented the routine and how she analyzed her student work. We used these videos to orient new teachers in the core network and to support the two BMTN-led improvement communities in Rhode Island. Exhibit 9 describes the organization of a professional learning activity involving the PDSA training videos.

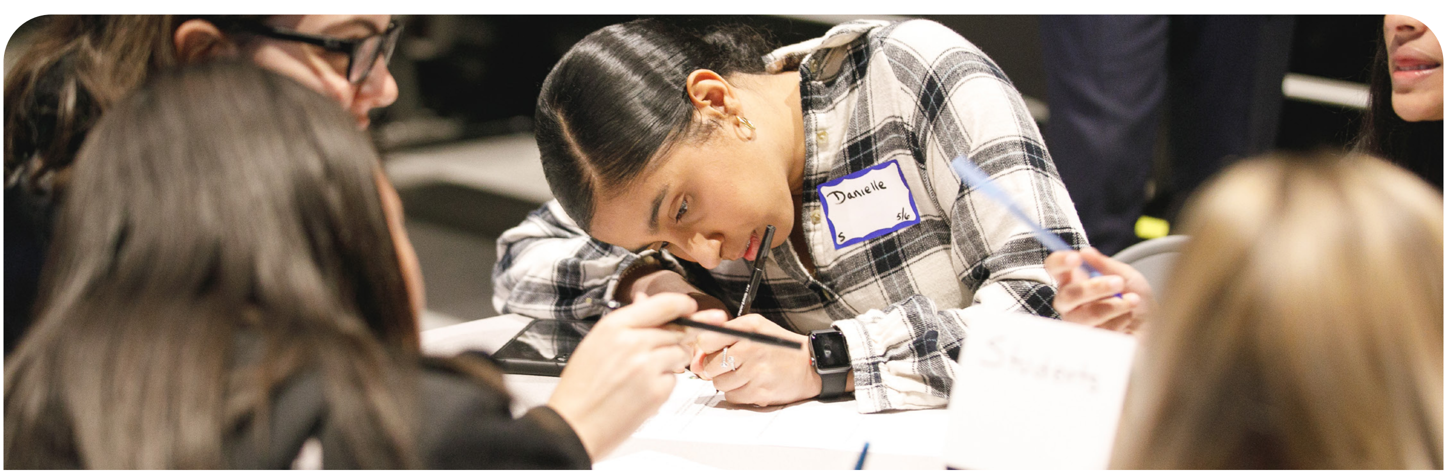


Exhibit 9. Professional Learning Activity using PDSA Training Videos

Activity	Description
PLAN	• Listen to teacher describe the problem she wants to address, her change idea, and how she plans to implement the change idea and measure progress • Complete the *Plan* section of the PDSA form
DO	• Watch classroom footage of the teacher implementing the change idea in her classroom. • Complete the *Do* section of the PDSA form
STUDY	• Analyze copies of student work that the teacher collected • Complete the *Study* section of the PDSA form • Listen to the teacher's analysis of the student work and identify similarities and differences between approaches
ACT	• Complete the *Act* section of the PDSA form • Listen to what the teacher decided to do and identify similarities and differences between the conclusions

Common rubrics. We developed a set of common rubrics, one for each focal math process (*connect*, *justify*, and *solve*), to provide teachers with common language and a common way to measure deep engagement in algebra. Exhibit 10 shows the rubric for *justify*. We hypothesized that these common rubrics would support spread of ideas among teachers because they would make the analyses and discussion of student work more focused and productive, which would better inform ongoing improvements instructional routines.

Exhibit 10. Common BMTN Rubric to Evaluate the Depth of Student Justifications

Justifying Superficially → **Justifying Deeply**

0	1	2	3	4
Logically connected responses				
No Response	Response is not logical or coherent because there are several missing connections.	Response is somewhat logical and coherent with at most a few missing connections.	Response is mostly logical and coherent but needs some organization.	Response is logical, and coherent throughout. All parts of the response are clearly connected to a prior step if there is a prior step and a following step if there is a following step.
Clear and precise use of math language (spelling does not matter)				
No Response	Response has inaccurate, missing, vague/generic, or unnecessary math language throughout the problem solving/in many areas.	Response has inaccurate, missing, vague/generic, or unnecessary math language in a few areas.	Response has inaccurate, missing, vague/generic, or unnecessary math language in one area.	All math language is accurately used and is appropriate for the problem.
If applicable, all terms, etc. defined and units specified				
No Response	Response includes terms, symbols, representations, measures but they are not defined or specified	Response includes terms, symbols, representations, measures and some are defined or specified	Response includes terms, symbols, representations, measures and all are defined or specified but the description is vague or unclear	Response includes terms, symbols, representations, measures and all are defined or specified and the description is clear
Math relationships (spelling does not matter)				
No Response	Response does not draw on math concepts or relationships. Instead uses just rules or procedures.	Response contains a few math concepts or relationships, but mostly relies on rules or procedures.	Response contains math concepts or relationships and rules or procedures and is evenly split between the two.	Response contains more math concepts or relationships than rules and procedures.

Teacher leadership. Finally, we offered three leadership opportunities to returning network teachers: leading PDSA testing groups, organizing a *Task Library* for teachers to find and share tasks that hold potential for promoting deep engagement in algebra, and supporting improvement work in their schools or districts. Nine network teachers participated in these leadership activities and some participated in more than one. Five teachers led PDSA testing groups, four teachers led a series of continuous improvement meetings in their schools or districts (one teacher was also a PDSA testing group leader), and two teachers led the development of the *Task Library* (one teacher also led continuous improvement meetings in her district).

Teachers who led PDSA testing groups engaged in their own improvement projects and then facilitated and guided the PDSA testing group to which they were assigned. Hub members did not attend these meetings. To become a PDSA testing group leader, teachers needed to have completed at least two years in the network and have experience working with teachers in a leadership role (e.g., mentor teacher, work with student teachers, instructional coach). Interested teachers completed an application and, once chosen, attended two training sessions. The first training session provided an overview of the role and hints for working with teachers. We emphasized the difference between being an PSDA facilitator, who focuses on the PDSA process, and an instructional coach or mentor, who provides guidance on how to improve instruction. In the second training session, PDSA testing group leaders reviewed a completed PDSA form and discussed how they would support the teacher in the PDSA process.

Teachers who organized and led improvement science meetings in their districts and schools did a variety of activities. One teacher led several-hour workshops in which she shared her experiences in using PDSA testing and encouraged others to do the same. Two teachers led a series of shorter meetings to support other teachers in implementing PDSA testing with a change idea of their choice. Still another teacher led a school-based PLC that used PDSA testing to refine strategies for implementing the collaborative learning structures that were embedded in their newly adopted math curriculum. We supported each of these teachers by providing guidance and materials that we used in our external PLC work.

Finally, teachers who led the development of the *Task Library* worked together to create a structure that would enable teachers to share, find, and rate tasks that have the potential to support deep engagement with algebra content. The *Task Library* is housed in a Google sheet, with tabs for each of the topics covered in Algebra I (e.g., functions, equations). Within each tab, teachers can view a list of tasks, the DEA(s) addressed, the type of task (i.e., short task, long task, discovery task), a description of the task, the source, and the teacher who submitted it. See Exhibit 11 for an example. Teachers submit tasks by completing a Google form. Once a task is submitted, it is reviewed to determine the extent to which it has potential for promoting deep engagement and, if it has enough potential, it is added to the library. When teachers use a task, they are encouraged to provide a review for others to see.

Exhibit 11. Sample Entries in the Task Library

Resource	Primary DEA	Secondary DEA	Task Type	Description	Source	Submitted by
Cafeteria By the Numbers	Connect	Solve	Discovery/ Exploration	Students are introduced to solving multi- step equations with a problem they are tasked to solve, then guided through understanding solving equations.	Inspired by MVP, adopted by Maria Keller	Martha
Candies Problem	Solve	None	Longer	This task helps students think about how equations can help them to work backwards through the situation to solve. Students can use guess and check or work backwards to start, but the goal is that by the end they see how they can create an equation to model the situation. It includes pre-thinking and reflection questions (second page) to help scaffold the solve process for students.	I adapted it from a puzzle/problem solving book – that I can't find or remember what it was	Shawn
Cell Phone Plans	Solve	None	Longer	This task presents a real-world problem requiring the students to write linear equations to model different cell phone plans. Looking at the graphs of the lines in the context of the cell phone plans allows the students to connect the meaning of the intersection points of two lines with the simultaneous solution of two linear equations.	Illustrative Mathematics	Alicia

NOTE: Teacher names have been changed.

Key Learnings

As we implemented structures and supports for spreading an understanding of PDSA processes and instructional routines to support deep engagement in algebra, we learned the following:

- Examples of PDSA testing, such as that demonstrated in our training video series, can support teachers in learning about and engaging in improvement processes with instructional routines.
- A common set of rubrics can support teachers in making improvements that have an impact on student engagement and provide a common language for sharing and learning about those improvements.
- Tools that teachers build, such as a *Task Library*, can support continued testing of instructional routines and build community among network members.

We found the videos of the PDSA process to be useful for spreading an understanding of how PDSA testing can be used to test and refine instructional routines. Not only did the video activity provide an opportunity for new teachers to become familiar with the process, it also provided a means for new and returning teachers to build a community with a common understanding of PDSA testing to improve instruction. The videos were also well-received by teachers in the external, BMTN-led improvement communities as they provided a model that teachers could use in their own testing of change ideas.

In contrast to other years, where teachers struggled to develop a meaningful measure of deep engagement, about 9 out of ten BMTN teachers used the common BMTN rubrics or close variations of those rubrics in their testing. We noted that the conversations in the PDSA testing group and whole-group network meetings were more focused with increased attention to the analysis of the evidence collected in each cycle and subsequent suggestions for improvement than in previous years. The rubrics appeared to provide a common language for discussing the data and associated modifications to the change ideas, which we believe contributed to improved data analysis and spread of key learnings relative to student-centered instruction. In addition, when used with teachers in the BMTN-led improvement communities, the rubrics offered a vision of deep engagement that teachers could draw upon in identifying and subsequently improving change ideas.

Finally, the *Task Library* was very well received by the network teachers. Teachers expressed appreciation for the resource and looked forward to hearing about new tasks at our network meetings. To date, 89 tasks have been reviewed and added to the *Task Library*. We anticipate more tasks being added to the library in the upcoming year.

Assessing Progress Towards the Aim

The network's efforts to foster the testing, refining, and sharing of promising instructional routines are intended to help the network reach its aim. As described earlier, the network aim is to increase the number of students who deeply engage in *connect*, *justify*, and *solve* by 2,019 by the year 2019. Our primary measure for tracking progress towards this aim has been a student survey, which we have administered to students of our core network teachers in the fall and spring of each year of the network. We also administer a similarly constructed teacher survey to core network teachers to track the frequency with which teachers provide students opportunities for deep engagement. We describe and present results from both surveys in this section.

Student Survey

Our student survey includes 14 core items that ask students to describe the frequency with which they enact behaviors that our network has associated with deep engagement in algebra. The survey has five items each for *connect* and *justify* and four items for *solve*.* Students select one of the following responses of frequency: *Never, Rarely, Sometimes, Often,* and *Almost Daily*. To track network progress, we examine overall scores on the survey as well as scores by each of these constructs. Exhibit 12 presents the survey items by construct.**

* 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

** Reliabilities (Cronbach's Alpha) for the survey: .91 (All items), .80 (Connect), .82 (Justify), and .78 (Solve).

Exhibit 12. BMTN Student Survey Items by Construct

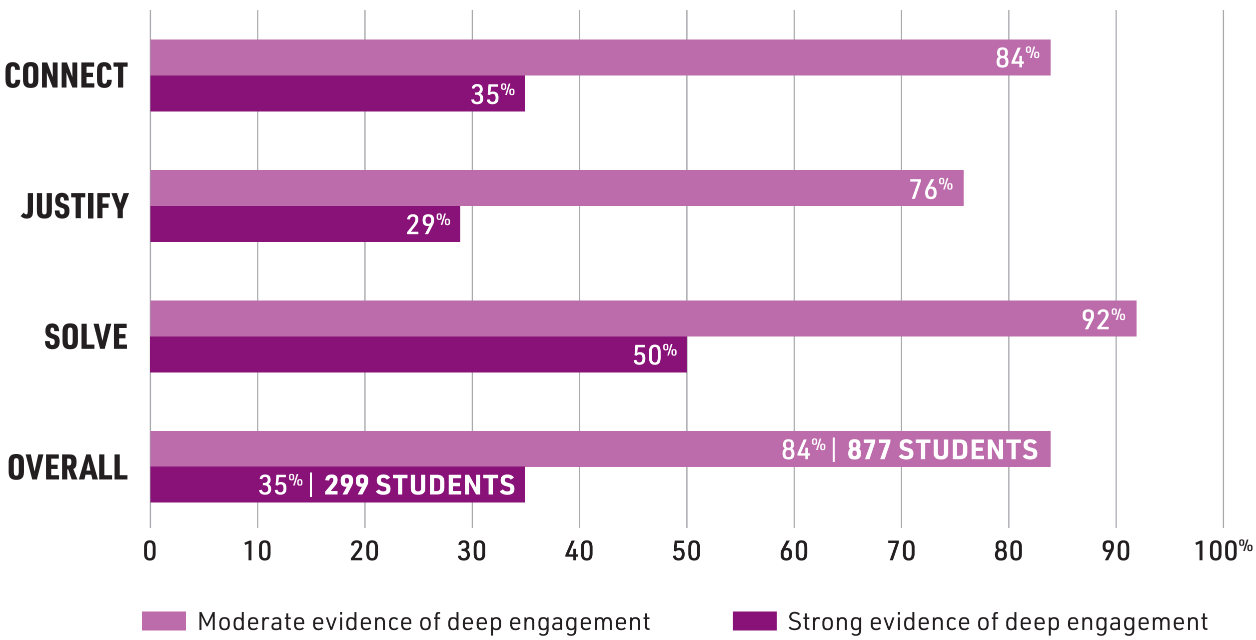
Survey Items by Construct and Overall
CONNECT. How often...
Do you make sense of mathematical rules, concepts, and relationships?
Do you make connections to math concepts from other classes you've taken before or in the future?
Do you make connections between math and real-world situations?
Do you examine 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...
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...
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?

DATA SOURCE: BMTN Student Survey, 2018-19 school year.

To measure deep engagement, we assigned values of 1 to 5 to each item on the survey: *Never* (1), *Rarely* (2), *Sometimes* (3), *Often* (4), and *Almost Every Class* (5). We do not expect students to be enacting all of these behaviors every day, since lessons have different learning goals and structures. On a test day, for example, students do not "explain their answers to others in class." Similarly, every lesson does not lend itself to students "mak[ing] connections to math concepts from other classes or in the future." Yet, if students *Never* or *Rarely* enact these behaviors, there is misalignment between the learning environments our network is trying to create and what students experience. Thus, we created two evidence levels of deep student engagement based on average scores of 3 or higher—i.e., responses of *Sometimes* or higher. Overall and by construct, average scores of 3 or higher provide *moderate evidence* of deep engagement and average scores of 4 or higher provide *strong evidence*.

Exhibit 13 shows the progress the network made towards meeting the aim during the 2018-19 school year. In spring 2019, roughly 84% of students (877 total) reported an average of 3 or higher across the 14 core items on the survey (moderate evidence of deep engagement). Within the group, 299 students, and 35% overall, reported an average of 4 or higher (strong evidence of deep engagement). *Solve* had the highest percentages of strong evidence (50%) and moderate evidence (92%), while *justify* had the lowest percentages of strong (29%) and moderate levels (76%).

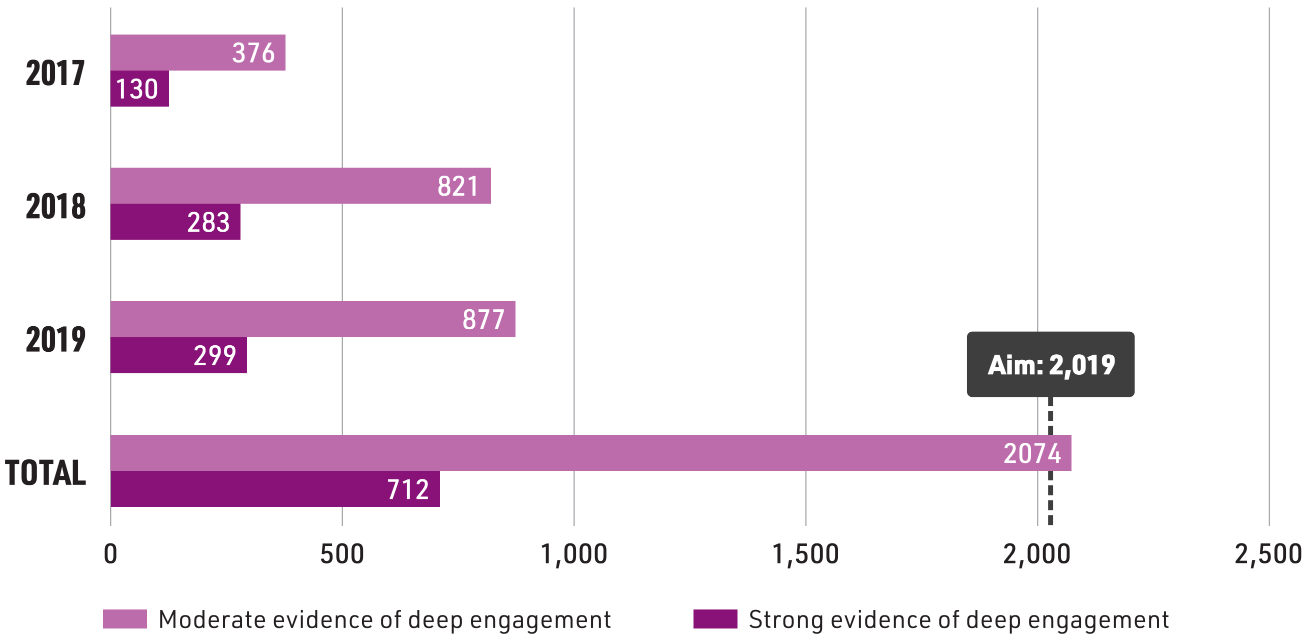
Exhibit 13. Percentage and Number of Students Deeply Engaged in Algebra, by Evidence Level and Dimension, 2018-19 School Year



DATA SOURCE: BMTN Student Survey, spring 2019; N = 1042.

Network reaches aim at the moderate level of evidence. Examining student engagement with these measures across the three years of the network illustrates overall progress towards the aim. Exhibit 14 shows the number of students who reported an average of 3 or higher and 4 or higher overall on the student survey in each network year and in total. Some 2,074 students provided at least moderate evidence of deep engagement in algebra, which exceeded our aim of 2,019. Among these students, 712 reported strong evidence of deep engagement.

Exhibit 14. Number of Students Deeply Engaged in Algebra, by Evidence Level and Network Year



DATA SOURCE. BMTN Student Survey, spring 2017 (N = 447), spring 2018 (N = 997), and spring 2019 (N = 1,042).

Putting BMTN student survey data in a broader context. These 14 core student survey items continue to help our network track progress towards the aim. But they do not describe how responses from network students might compare with samples of students from other schools, districts, and states. For comparison purposes, we added five questions to our 2019 survey from the Tripod,[6] a widely used student survey that has items that are well-aligned to the goals of the BMTN. The Tripod uses a five-point scale to capture the degree to which students determine that a given statement is true, ranging from "totally untrue" to "totally true." In a prior study using the instrument, the top two responses—"mostly true" and "totally true"—were collapsed to indicate student agreement with each question.[7] Classrooms in which 50 to 80 percent of students responded at these top two levels of agreement across the survey were in 75th percentile of the study sample. Classrooms rated at this percentile or above had higher levels of student math achievement than classrooms at the 25th percentile and below. We only used a subset of Tripod survey items, but at the item level, BMTN students agreed at levels at or above classrooms at the 75th percentile in the prior study. Exhibit 15 lists the BMTN student agreement rates—all at least 80%—for each question from the Tripod.

Exhibit 15. Tripod Survey Items and Levels of BMTN Student Agreement

Thinking of this class ...	Totally or Mostly True
My teacher accepts nothing more than our full effort.	**80%**
My teacher wants me to explain my answers—why I think what I think.	**82%**
My teacher doesn't let people give up when the work gets hard.	**84%**
My teacher wants us to use our thinking skills, not just memorize things.	**84%**
My teacher asks students to explain more about the answers they give.	**83%**

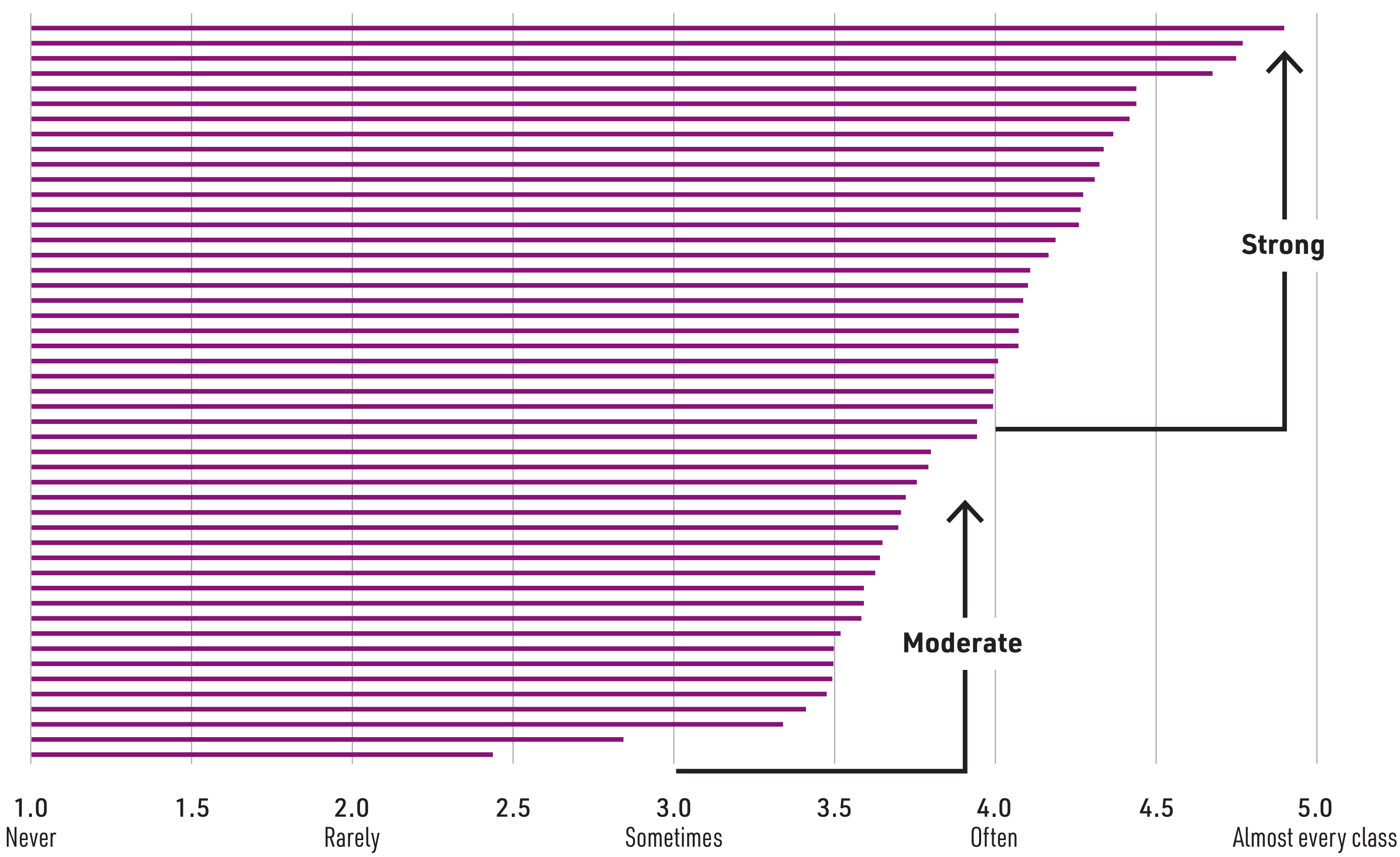
DATA SOURCE: BMTN Student Survey, 2018-19 school year, N = 1,042.

Teacher Survey

Using the same core item content from the student survey, we asked teachers to report the frequency that they provided students with opportunities for deep engagement. For example, "How often do you make sense of mathematical rules, concepts, and relationships?" from the student survey is modified to "How often do you *provide students with opportunities to* make sense of mathematical rules, concepts, and relationships?" on the teacher survey. The five response options from the student survey are the same on the teacher survey. We used the same method to determine moderate and strong levels of evidence: average scores of 3 for moderate and above and 4 and above for strong evidence.

All but two of BMTN teachers indicated that they provided opportunities for deep student engagement at the moderate level, which is perhaps expected given teachers' active participation in the network and PDSA testing. Yet, as shown in Exhibit 16, there was variation among the teachers across these levels.

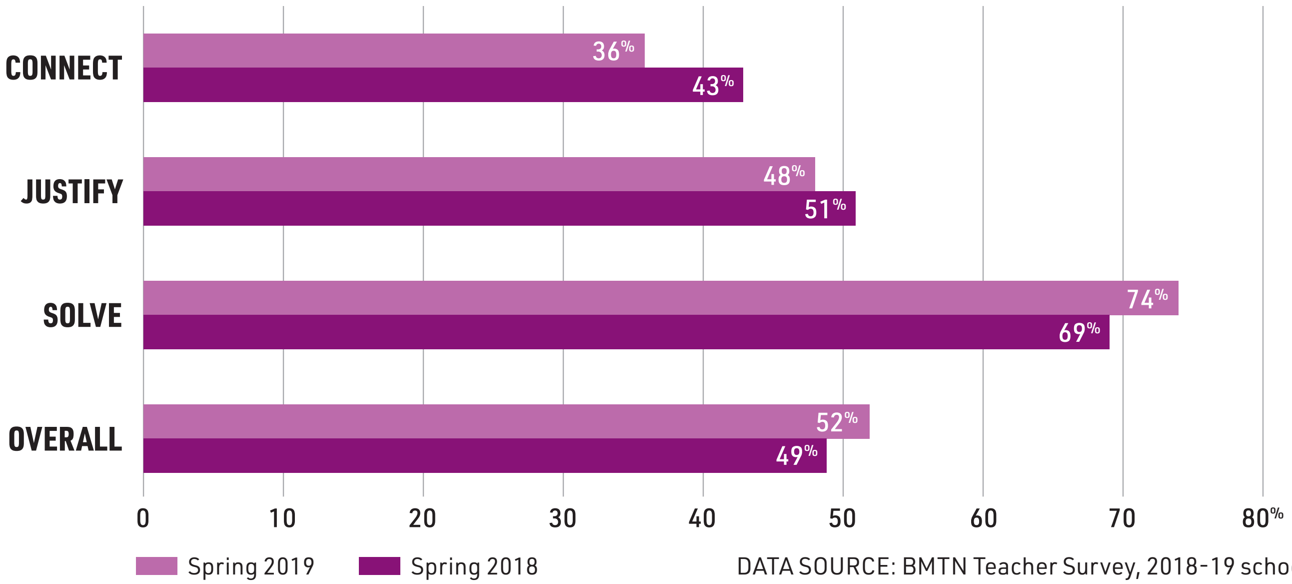
Exhibit 16. Frequency Teachers Provided Opportunities for Deep Student Engagement, by Evidence Level, 2018-19



DATA SOURCE: BMTN Teacher Survey, 2018-19 school year, N = 52.

At the strong evidence level, just over half (52%) of BMTN teachers reported at this level of engagement across the survey in Spring 2019. For each dimension, teachers reported providing opportunities for *connect*, *justify*, and *solve* at 36%, 48%, and 74%, respectively. As shown in Exhibit 17, these percentages are comparable to what teachers reported in spring of 2018, by dimension and overall.

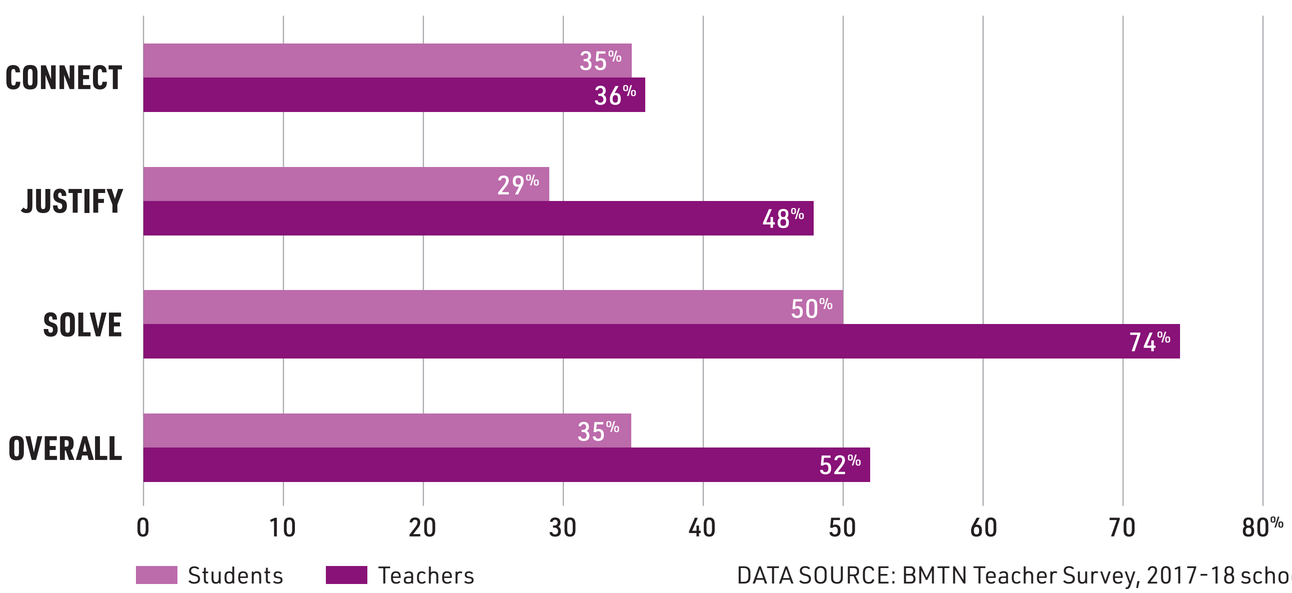
Exhibit 17. Percentage of Teachers Providing Opportunities for Deep Student Engagement at the Strong Evidence Level, Spring of 2018 and 2019



DATA SOURCE: BMTN Teacher Survey, 2018-19 school year, N = 52.

Exhibit 18 compares the opportunities teachers provided for deep engagement at the strong level with what students reported. For each math process and overall, the opportunities teachers provided for deep engagement at the strong level were higher than the behaviors reported by students for the corresponding survey question. For example, across the survey, 52% of teachers reported providing opportunities for deep engagement at the strong level, compared to 35% for students. *Connect* was the only process in which both the opportunities provided and levels of student enactment were almost the same—36% for teachers and 35% for students. The math process with the biggest difference was solve: 74% for teachers and 50% for students, a difference of 24%.

Exhibit 18. Percentages of Opportunities for Deep Student Engagement at the Strong Level, Teachers and Students, 2018-19 School Year



DATA SOURCE: BMTN Teacher Survey, 2017-18 school year, N = 52.

What's Next?

The network is now entering its fourth and final year. With each year as a network, our understanding of student-centered instruction, as we have defined it, has deepened and we expect this to continue in the upcoming year. We plan to continue to (1) develop and test new instructional routines that are designed to deepen student engagement and improve instruction; (2) spread promising strategies inside and outside the network; (3) support teachers as instructional leaders in their schools and districts; and (4) publish findings for math education and improvement science audiences.

More specifically, for spreading our work and building teacher instructional leadership, we plan to devote additional resources to support BMTN teachers in lead professional learning communities in their local math departments and facilitate a learning community for these leaders. The support will include providing refined training materials to teachers, which they can use to guide meetings next year and even beyond.

We will continue to collect and analyze data that demonstrate progress we are making as a network, as well as areas for improvement. In spring 2020, we plan to collect and analyze videos of BMTN teachers' instruction as well as a measure of students' problem-solving skills. These data sources will be used to complement the student and teacher survey data we use to track progress towards the aim. Given how relatively new NICs are in education, publishing findings from our work will contribute to the growing evidence for this model of collaborative improvement.

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