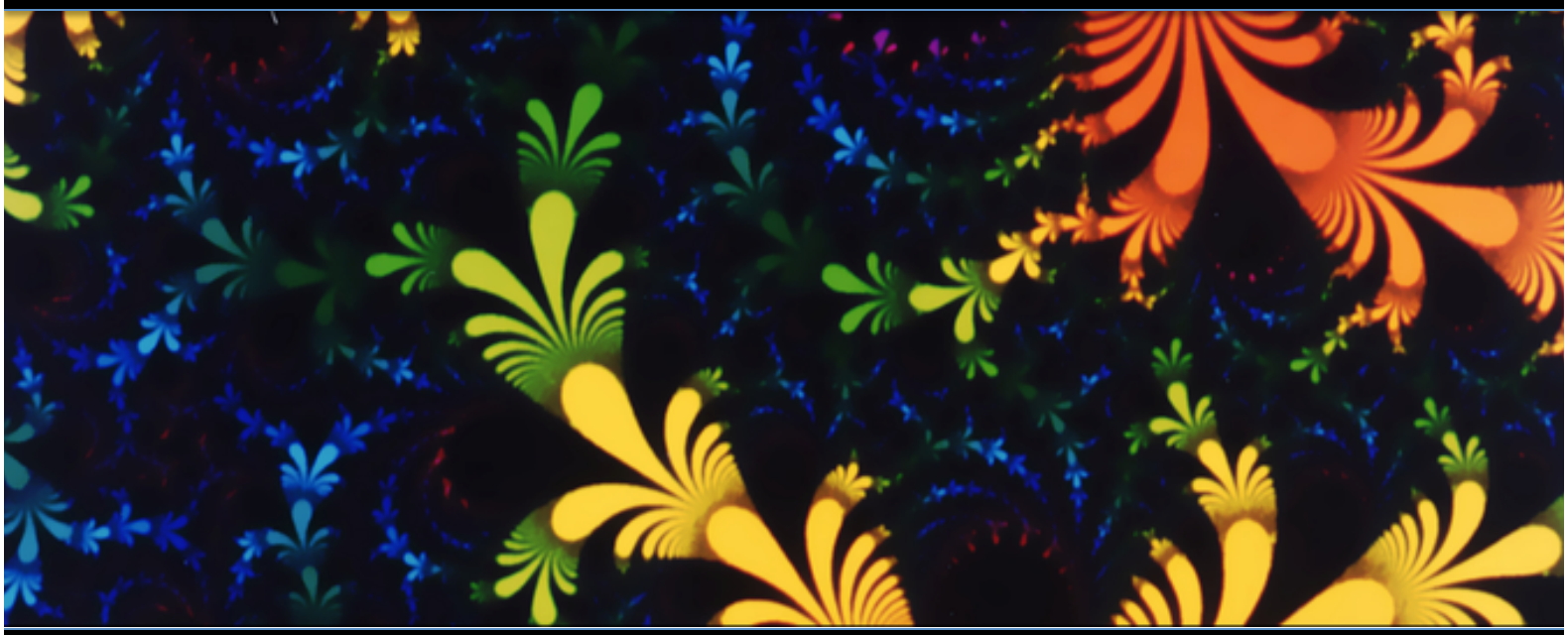
Delaware K-12 Mathematics Partnership Project

A Delaware Mathematics Coalition & University of Delaware MSP Project



Mathematics Science Partnership Program
Annual Performance Report
2014-2016

ABSTRACT

The core challenge of the **Delaware K-12 Mathematics Partnership Project** was to support Delaware teachers and their students in exemplifying the content and practices described in the Common Core State Standards for Mathematics (CCSSM). The project was the conceptualization of the Delaware Mathematics Coalition (DMC). Monthly meetings of the DMC provide opportunities for K-12, higher education, department of education, and business partners to engage in meaningful conversations related to their roles as instructional leaders, their mutual efforts to share best practices and problem solve challenges, and their desire to become more influential and persuasive agents of change. As a learning community, DMC members continually demonstrate their strong commitment to the organization's mission, their vision for creating more powerful and robust mathematics teaching and learning environments, and their collective efforts to build state, district, and school-based mathematics leadership capacity. The goals of the **Delaware K-12 Mathematics Partnership Project** were based on priorities that emerged from DMC members' conversations and their analysis of school and district needs surveys, state and school-level student achievement data, and recommendations from past MSP evaluation reports.

Using a cohort-based structure designed to meet the diverse needs of the teachers, specialists, coaches, and administrators from thirteen Delaware school districts, six charter schools, and faculty from three institutions of higher education, the **DE K-12 Mathematics Partnership Project** engaged participants (n=230), grouped by learning strands, in sustained, recursive and meaningful professional learning opportunities totaling 60 hours of face-to-face time. Specialized leadership strands for teacher-leaders [n=40] and coaches [n=30] provided additional hours of instruction and support for the content-focused coaching and video-based action research goals in the project. This resulted in more than 80 hours of professional learning for these leaders each year. The content-based learning trajectory experiences were grounded in research on conceptual understanding (Hiebert & Grouws, 2007) and purposefully designed to enhance and extend the state's Common Core efforts by: 1) increasing the content and pedagogical knowledge of teachers, coaches, and administrators, particularly in areas that support the focus and level of rigor called for the in Common Core State Standards for Mathematics; 2) engaging students in deeper and more enduring learning experiences that *routinize* the Standards for Mathematical Practice; 3) increasing student achievement using metrics that are aligned with national assessments; 4) improving students' motivation to pursue STEM-centric studies upon graduation from high school; and 5) developing teacher leadership and school-based instructional capacity and infusing the school environment in a culture of professional growth and reflection. Higher education partners for the project included the University of Delaware, Delaware State University, and Wilmington University with University of Delaware's (UD) Professional Development Center for Educators (PDCE) and Mathematical Sciences Department (MSD) playing a more central role in the professional development and fiscal management for the project.

Project facilitators included mathematicians and mathematics educators from the University of Delaware, the National Council for Teachers of Mathematics, local professional development experts with a long history of success in K-12 schools, and classroom-based practitioners who were evolving as strong professional development providers. Using CCSS-inspired problem-based tasks and routines, facilitators supported teachers' in implementing new CCSS-inspired instructional practices and targeting conceptual understandings and fluencies that have historically served as barriers to success in students' mathematical careers. These "gatekeeper" topics included: building procedural fluency in place value operations and number structures, fractions, proportional reasoning, connecting numeric/algebraic reasoning, generalization and

reasoning, and modeling. Monthly professional development sessions provided ongoing opportunities for the participants to actively engage in grappling with challenging problem-based tasks, creating viable arguments and critiquing the reasoning of others, and planning for ways to translate their inert knowledge to *usable* knowledge in their classrooms.

Research links the success of teacher content training to the level of support teachers receive upon returning to their school settings (Guskey, 2009). To address this challenge, project leaders created a set of additional structures [Online *Schoology* Study Group, Leadership Coaching Lab, PBL Chats, & K-16 Community events] to promote job-embedded learning opportunities for teacher-leaders, coaches, and administrators. Monthly sessions of *Leadership Coaching Lab* engaged school/district coaches and mathematics specialists in content-focused coaching experiences. As part of their action research work, teacher-leaders collected and analyzed of CCSS-inspired video, rehearsed sharing their video during cohort meetings, and returned to their school PLC meetings prepared to promote mathematically rich conversations about the videotaped lessons with their peers. The use of resources such as *The Art of Coaching* (Aguilar, 2013) and *Crucial Conversations: Tools for Talking When Stakes Are High* (Patterson, 2009*)* helped teacher-leaders and coaches acquire important relational skills necessary for promoting more productive and powerful school-based conversations. Monthly PBL Chats provided opportunities for the district stakeholders to engage in problem-based learning experiences with university math professors. The collaborative structure fostered K-16 networking, promoted a shared vision for STEM-centric teaching and learning, and provided a forum for actively and publicly developing a joint-agenda for change. As a result of the combined cohort-based and specialized leadership work, project participants could accrue as many as 100 hours of focused face-to-face learning each year.

Horizon Research, Inc. (HRI), a nationally recognized organization with extensive experience evaluating mathematics/science projects served as the project evaluator. HRI provided an independent perspective on the project's work utilizing both formative and summative measures to assess the quality and impact of the professional development and onsite coaching efforts. Formative metrics focused on the quality of project activities, enabling project leaders to make mid-course corrections. The summative component of the evaluation focused on assessing the impact of the professional learning and school-based DECAL work on teachers, administrators, and their students. Project deliverables included video-based professional development modules, supporting documents outlining the research rationale for each course-of-study, local and national mathematics education publications, and increased numbers of project-related presentations in local and national mathematics leadership conferences.

FOUNDATIONAL RESEARCH

The Delaware Mathematics Coalition professional learning strands were purposely developed to promote effective and innovative evidence-based mathematics instruction and classroom environments in which opportunities for student learning are maximized and where all students are supported in becoming more confident and competent *doers* of mathematics.

The Standards for Mathematical Practice describe varieties of expertise that mathematics educators at all levels should seek to develop in their students. These practices are predicated on important "processes and proficiencies" with longstanding significance in mathematics education (Common Core State Standards, 2011).

***Principles to Action's* Teaching Practices** serve as a research-informed framework for strengthening the teaching and learning of mathematics. The core set of eight high leverage practices have been identified as essential components of instruction that is aimed at promoting a deeper understanding of mathematics (NCTM, 2014).

Building Conceptual Based Understanding that Promotes Student Learning

A meta-analysis of educational research (Hiebert and Grouws, 2007) documents two principles for improving deeper, conceptual understanding of mathematics. The principles include:

1) providing opportunities for students to grapple with challenging problems; and
2) making the connections between key ideas explicit.

These research principles are central components of content and pedagogical work for each of the Delaware Mathematics Coalition course-of-study learning strands.

Promoting Sustainable Changes in the Era of the Common Core in the Era of the Common Core

The Delaware Mathematics Coalition is committed to supporting Delaware teachers, coaches, specialists, and administrators in their efforts to successfully implement the content and instructional practices described in the Common Core State Standards.

A substantial body of research points to *teachers* as the *most important* factor in promoting mathematics learning (McCaffrey, Lockwood, Koretz, & Hamilton, 2003). The education of teachers is an essential aspect of educational improvement and as such, the professional development of *practicing teachers* is a requirement for the successful enactment of the CCSS-M.

Using a progression of learning that is aimed at meeting the diverse needs of teachers and administrators in partnership schools, project facilitators including local and nationally recognized math educators and mathematicians engage participants in a cohesive series of linked professional development experiences designed to build across a content and pedagogical trajectory. The project furthers the state's agenda for change by:

- increasing teachers' content knowledge, particularly in areas that support the focus and level of rigor called for the in CCSS-M;
- engaging students in deeper and more enduring learning experiences that exemplify the Standards for Mathematical Practice;
- increasing student achievement using both state and other metrics that are aligned with the targets on new national assessments;
- developing teacher leadership and school-based instructional capacity; and
- immersing teachers and school groups in a culture of professional growth and reflection.

Professionalism

"In an excellent mathematics program, educators hold themselves and their colleagues accountable for the mathematical success of every student and for their personal and collective growth toward effective teaching

The DMC's Vision for Conceptually-Based Mathematics Teaching & Learning

In a conceptually-based mathematics lesson, the bulk of the cognitive work of learning is done by the students, with the teacher orchestrating productive interactions between mathematics and learners. Typically, a conceptual lesson begins with the introduction of an appropriately challenging "group-worthy" problem or task, one that has multiple entry points, requires students to actively *grapple,* and supports collaborative problem solving (Lotan, 2003; Hiebert & Grouws, 2007). The purpose of the launch is to *engage* the students in the mathematics central to the task and to *promote access* to the math for all students (Lampert, 2001; Horn, 2012). Promoting access for all students must be balanced, however, with the need to establish and maintain the cognitive demand of the task (Stein et al., 2000).

In a high-functioning conceptually-based math lesson, the students first engage the task individually to develop a mind-hold on the relevant mathematics and then come together in pairs or small groups to share perspectives on the problem and to work collaboratively toward a solution (Slavin, 1991). The teacher's role during this investigation/inquiry phase of the lesson is to *listen to* student solution attempts rather than *listening for* particular answers and to ask probing questions that prompt more effective problem solving and collaboration (Fennema, Carpenter, & Peterson, 1989). The teacher's questions should *focus* attention on important aspects of the problem, without *funneling* students into a particular solution strategy (NCTM, 2014). This process is enhanced when teachers have made an effort (in advance) to anticipate how students might respond to the task at hand, considering questions they might ask to probe and support connections, build on prior knowledge, and promote student understanding around the desired learning goal(s) for the lesson (Smith & Stein, 2011; NCTM, 2014).

An important aspect of the teacher's facilitation of the investigation phase is to "manage the clock" – too much time allocated to this phase of the lesson may decrease the sense of urgency that promotes successful collaboration, too little time undervalues student struggle and reasoning. The strategic use of distributed shares serves to promote expanded access to evolving ideas and processes and ideally results in more productive grappling during the problem solving endeavor (Marzano, 2001; NCTM 2014). Whole class discussions provide a forum for the teacher to underscore the value of student ideas and explanations rather than simply problem resolution. As students develop solution strategies, they are called upon to construct viable arguments and listen and respond to one another's mathematical argumentation (CCSS, 2009). In some instances, the teacher may provide extensions to the problems for students who have solved the initial task and are ready to probe the mathematics more deeply.

Finally, the teacher has the responsibility to help students make explicit connections between key mathematical ideas and to promote as much of a consolidation of the learning as possible (Ball 1993; Lampert, 2001; Boaler & Humphries, 2005; Hiebert & Grouws 2007). This usually involves the teacher prompting carefully selected groups to share their solution strategies in front of the whole class. The teacher is also mindful of sequencing these student presentations in the order that would seem to maximize the learning goals for that lesson (Smith & Stein, 2011). A particularly challenging aspect of this phase of the lesson is to promote a genuine and productive interaction between student presenters and the other students in the class. Instead of the teacher simply summarizing what she believes students have learned, the students come to rely on each other as mathematical authorities, understanding each other's mathematical reasoning becomes the ultimate arbiter for sense-making in the mathematics classroom (Webel, 2010).

Inspired by members of the New Normal MSP Project. Original composition by Jon Manon (2011) in collaboration with the New Normal Project leadership team. Subsequent revisions made in 2014 by Jamila Riser, Valerie Maxwell, and Corey Webel. For more information, please contact Jamila Riser jqriser@gmail.com

DE K-12 Mathematics Project Professional Development Model

Established more than a decade ago, the Delaware Mathematics Coalition promotes a vision for learning that is grounded in research and embodies the following guiding principles:

- Students learn mathematics by thinking hard (grappling) and through interaction;
- Student sense-making should be at the core of all mathematics instruction;
- Fluency evolves over time as conceptual understanding is strengthened and deepened;
- All students can come to view themselves as competent *doers* of mathematics; and
- For communities of educators to shift their practice in meaningful ways, they must have ongoing opportunities to learn mathematics in the ways that they are expected to teach mathematics.

The design of the **DE K-12 Mathematics Partnership Project** professional development program reflected these principles and was structured to support the evolving content-focused and practices-based needs of district practitioners. The professional development targeted 230 teachers, coaches, and administrators, providing 60 hours of face-to-face instruction for all participants. Participants attended five full day teacher release days, a four-day summer academy, two K-16 Statewide Seminars, and four after-school meetings for the forty teachers in the leadership group, with on-site coaching support for the leaders as they engaged in school-based DECAL work. An additional 8 days of collaborative coaching training was provided for math specialists and coaches, expanding the state's capacity to provide school and district structures for meaningful mathematics teaching support.

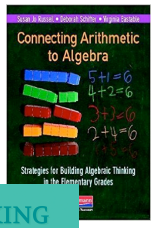
The content focus for each cohort course-of-study was based on an analysis of statewide achievement data, a needs assessment of DE curriculum directors, research recommendations connected to the CCSSM, and the grade level focus areas embedded in the Department of Education's Common Ground Common Core effort. Participants engaged in selected learning strands configured to address identified mathematics targets, specific grade level clusters, and the participant's level of experience in the project. The goals for the secondary cohorts [New Normal] were also linked to a graduated set of high leverage pedagogical practices that focused participants' attention on specific *connecting-to-practice* work to implement in their classrooms. Within each cohort, professional development leaders including university mathematicians and expert facilitators with a history of success in the state routinely addressed the depth and rigor of the CCSSM and promoted CCSS-inspired practices by modeling rich, appropriately challenging math tasks in an interactive, collegial setting. Project facilitators also called explicit attention to research-based instructional practices (NCTM, 2014) for promoting strong conceptual understanding (Hiebert & Grouws, 2007). The experiences were grounded in problem-based learning with recursive opportunities to unpack the storyline for the mathematics lesson as well the nature of their engagement in the Standards for Mathematical Practice (CCSSM, 2010).

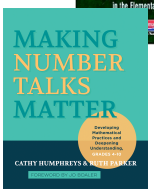
Working in collaboration with school and district coaches, site-based coaches engaged teacher leaders in content-focused, video-based Designing Effective Collaborations Around Learning (DECAL) cycles. The learning was situated within a lesson study structure facilitated by project and/or school-based coaches. The leaders applied the content they were learning in the leadership and coaching strands to engage their peers in mathematically intense conversations related to their videotaped lessons, promoting a more analytical reflection of the data by using nonjudgmental language, and focusing on evidence of students' progress toward the desired learning goals for the day. Artifacts from the DECAL sessions were collected and later featured in professional development segments led by the teacher leaders and coaches in the project.

UNDERSTANDING THE BEHAVIOR OF OPERATIONS

Elementary Math Teacher Leadership Professional Development

Building Procedural Fluency on Conceptual Understanding: Inspired by the Standards of Mathematical Practice and research by Russell, Schifter, and Bastable, (2011), elementary teachers learn foundations of algebraic reasoning by delving deeper into number:





- Noticing regularities and structure in number;
- Constructing and investigating conjectures about their observations;
- Using multiple representations to support claims about number properties;
- Articulating viable arguments & critiquing the reasoning of others; and
- Comparing & contrasting operations.

Participants build representations-based content knowledge, and read and discuss research on student's foundational learning and number operations, with an emphasis on findings taken from *Connecting Arithmetic to Algebra*, and *Making Number Talks*

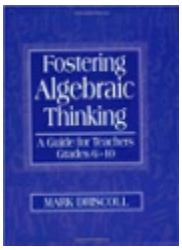
"At the heart of mathematics is posing one's own questions about mathematical relationships. To truly engage in mathematics is to become curious and intrigued about regularities and patterns, then describe and explain them. Making generalizations about how operations behave is an essential mathematical activity and important as an object of study" (Russell, Schifter, Bastable, 2011).

Toward A New Normal in Secondary Mathematics Instruction

Cohort One Professional Development Strand

Content Focus: Generalization in the Context of Algebraic Thinking

Inspired by research by Kaput (1993), Vance (1998), and Driscoll (1999), the *New Normal Cohort 1* course-of-study is purposefully designed to achieve the following *Common Core* aligned learning outcomes:



- Understand repeated reasoning, structures, relationships, and functions;
- Represent and analyze mathematical situations using algebraic reasoning and symbolic notation;
- Use and connect mathematical representations to increase conceptual understanding and procedural fluency; and
- Analyze rate of change and promote connections between recursive and explicit generalizations.

Creating A CCSS-Inspired Problem Based Math Classroom

Based on research from NCTM's *Principles to Actions* (2014), the *New Normal* professional development program is designed to support teachers in achieving the following success targets:

- Use rich tasks in order to promote more robust problem solving endeavors
- Make student thinking public and orchestrate student led presentations
- Utilize classroom structures and routines to promote listening and increased engagement in one another's ideas
- Support students in productively grappling with important mathematics
- Value and connect different solution paths in rich problem-based tasks

Toward A New Normal in Secondary Mathematics Instruction

Cohort Two Professional Development Strand

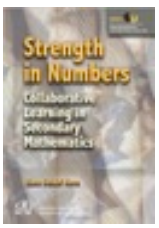
Generalization, Justification & Proof in the Context of Geometric Thinking

Based on research from *Characterizing Students' Understanding of Mathematical Proof* (Knuth & Elliott, 1998) and Driscoll's (2009) *Fostering Geometric Thinking*, the *New Normal Cohort 2* course-of-study is purposefully designed to achieve the following *Common Core* aligned learning outcomes:

- Visualize geometric figures from a dynamic perspective rather than solely from a static point of view;
- Represent geometric relationships in multiple ways;
- Use Knuth's framework, recognize and support mathematical abstractions and proof;
- Arithmetize and algebrafy (generalizing) geometric properties; and
- Explore and recognize transformations, including translation, reflection, rotation, and dilation on an object as well as it's corresponding function or relational representation.

Promoting Content-Focused Discussions

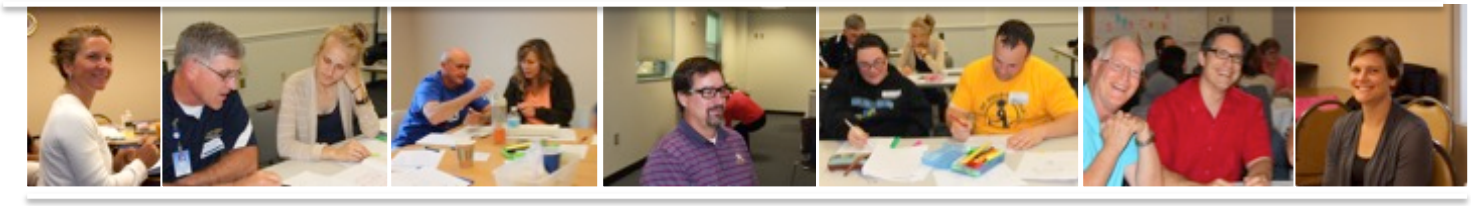
Grounded in the research from *Strength in Numbers* (Horn, 2012) and building upon the pedagogical and equity work from year one, *New Normal Cohort 2* teachers will focus on the following success targets:



- Positioning students in ways that support richer, more mathematically productive small-group and whole-class discussions
- Promoting a classroom climate where students routinely analyze and compare one another's approaches and arguments, respectfully question and debate one another, and build a shared understanding of mathematical ideas

Toward A New Normal in Secondary Mathematics Instruction

Cohort Three Professional Development Strand



Reasoning, Justification, & Generalization in the Context of Probability & Statistics

Based on research on student difficulties in learning fundamental concepts in probability and statistics, e.g. Shaughnessey & Grouws (1992), the *New Normal Cohort 3* course-of-study is purposefully designed to achieve the following *Common Core* aligned learning outcomes:

- Investigate chance processes and develop, use, and evaluate probability models;
- Draw comparative inferences about two populations;
- Investigate patterns of association in bivariate data; and
- Understand and evaluate random processes underlying statistical experiments and use *probability* to inform decision-making.

Shifting the Authority: Helping Students Own the Mathematics

Building on the pedagogical and equity work from years one and two, the *New Normal Cohort 3* success targets are inspired by research conducted by Elizabeth Cohen & Rachel Lotan (2014):

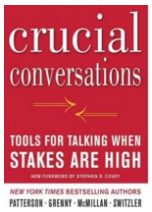
- Address issues of status and perceived mathematical competence in small and whole group settings
- Shift the mathematical authority by supporting students in becoming better *problem posers* and *problem solvers*




New Normal in Secondary Mathematics Instruction Program

Designing Effective Collaborations Around Learning (DECAL)

Inspired by research by Kaput (1993), Vance (1998), Driscoll (1999), and Pershan (2014), the New Normal Cohort 4 course-of-study is purposefully designed to achieve the following learning outcomes:

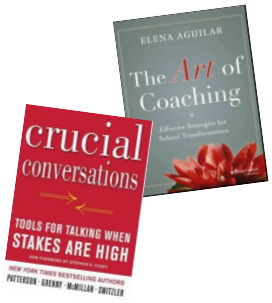


- Understand repeated reasoning, structures, relationships, and functions for general cases of mathematical situations;
- Connect mathematical representations to increase conceptual understanding and procedural fluency;
- Analyze rate of change and support translations between recursive, relational, and functional ways of reasoning;
- Utilize video from their Designing Effective Collaborations Around Learning (DECAL) cycles to lead mathematically intense conversations, particularly with regard to supporting productive grappling and making key ideas and connections explicit (Hiebert & Grouws, 2007); and
- Practice and adopt skills to successfully engage in crucial conversations.

"Participants described how by doing math together they built shared commitments to improving teaching and learning. They spoke of professional development as a community in which they could explore new ideas and approaches, take risks with the support of peers, and reflect on themselves as educators and that being in the community of other 'math people' complemented and extended the participants' personal work of thinking about math and about themselves as teachers and learners. By supporting teachers and administrators as learners, the professional development modeled what the participants' own departments and classrooms could be like as communities devoted to learning through problem-based mathematics."

Building Leadership Capacity

The promise of the *Leadership Coaching Lab* is to build a robust mathematics community in which the role of teacher collaboration around classroom instruction is public and itself the focus of study among colleagues. We emphasize the powerful potential activated by teacher leaders, coaches, and math specialists engaging with colleagues to:



- Plan for problem-based instruction.
- Promote mathematically intense planning and teaching conversations.
- Use protocols for analyzing classroom videos.
- Practice relational skills to build a school culture of collaboration.
- Study research on mathematics practices that improve student learning.
- Interact around student learning in ways that are evidence-based, collegial, and non-defensive.

DE K-12 Mathematics Leadership Community

DESIGNING EFFECTIVE COLLABORATIONS AROUND LEARNING (DECAL)

The DE K-12 Mathematics Leadership Community supports the ongoing professional growth of teacher leaders, coaches, and administrators from the K-12 partnership schools. Participants of this community engage in action-research study groups, collect video, and provide leadership in their schools and districts. This year's community focus on exploratory talk and connections to learning have been led by Dr. Amanda Jansen (UD School of Education).

DE K-12 Mathematics Partnership Project Evaluation

Horizon Research, Inc. (HRI) conducted the external evaluation for the **DE K-12 Mathematics Partnership Project**. HRI has over 25 years of experience evaluating both small and large-scale mathematics and science improvement projects. HRI provided an independent perspective on the project's work and contributions included both formative and summative components. The formative component focused primarily on the quality of project activities, enabling project leaders to make mid-course corrections where needed. The summative component of the evaluation was designed to measure the project's impact on teachers, administrators, and students, as well as providing a critical review of the project's research, without duplicating the project's own efforts.

HRI's evaluation of the **DE K-12 Mathematics Partnership Project** was guided by the following research questions:

1. What is the quality of the teacher professional development and its implementation?
2. What is the quality of project activities designed to further leadership capacity and administrative support for improving mathematics classroom practice?
3. What are impacts of the program on teachers' mathematical knowledge for teaching?
4. In what ways do teachers change their instructional practice after participating in the program?
5. How is student achievement related to the project's work with teachers and administrators?

Quality of the Professional Development: To assess the quality of the project professional development and leadership work, HRI observed selected sessions of the EMTL & New Normal cohorts, administered surveys, conducted focus-group interviews, and case studies involving highly engaged teachers, coaches, and administrators in the project. Observation and interview protocols were adapted from the Core Evaluation of the LSC program (http://www.horizon- research.com/LSC/manual/). Data from those sources was analyzed qualitatively, comparing project activities to best practices in effective professional development and systems change (e.g., Elmore, 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001), and the extent to which project activities are perceived to address participants' needs.

In the first year's evaluation summary, HRI indicated that the overall structure, focus, and approach within the cohort-based sessions of EMTL & New Normal mirrored the characteristics of high quality PD consistent with the researchers' framework. In particular, HRI stated:

"The instructional design incorporated mathematical activities that motivated and modeled the style of instruction being promoted, discussions and readings about teaching practices, and opportunities for reflection. The professional development goals for mathematics instructional practices were shared with participants, and the cohort design provided opportunities for individual participants to continue strengthen their practice as they achieved interim goals following previous years' professional development. Participants built connections within and across schools through group activities at the PD, and administrators were included in the PD opportunities. Finally, the project members made use of assessment and evaluation data to adjust and improve the PD."

HRI provided ongoing feedback to project leaders to inform design and implementation decisions and actions. Project leaders collected data annually on teachers' mathematical knowledge for teaching, using both nationally-normed and self-made items. HRI administered multiple surveys to measure teachers' preparedness to implement, and implementation of the teaching practices addressed in the professional development. Survey items were selected from a range of sources including the Core Evaluation of the LSC, Cases of Reasoning and Proving in Secondary Mathematics (NSF #0732798), Mathematics Discourse in Secondary Classrooms (NSF #0918117), and the elementary-grades focused All Included in Mathematics (NSF #1020177) projects. The surveys were administered at the end of each year of teachers' participation in project professional-development and were included in "retrospective pre" scales for teachers to report prior, as well as current, preparedness and practices. This approach accounts for shifts in respondents' frame of reference that can underestimate effects (Pratt, McGuigan, & Katzev, 2000)).

In the final year of the project, HRI evaluators noted that the "DMC has a clear vision for effective instruction and the targeted PD content to support teachers' instructional practices" (2016) and staff members routinely made use of informal and formal opportunities to gauge participants' understanding during the PD sessions. During debriefing sessions observed by HRI researchers, HRI observers stated that facilitators were highly reflective about both the facilitation strategies they had used and the effectiveness of the PD sessions (2016). Researchers also note that the PD goals for mathematics instructional practices were shared with participants, and the successive nature of the content in the cohort design provided opportunities for participants to continue to strengthen their practice as they achieved interim goals following the previous years' PD. The impact of the PD on teachers and administrators was expressed by participants during interviews.

"My assistant principal came to almost everything. I think it was an excellent opportunity. He was new to our school, new to supervising math, and he was able to see what approach it was, what philosophy it was that we had. When we learned something at the PD, we would come back and talk about it, like hey what do you think of that, or is this going on in our classrooms? Hey let's do walk-throughs together and see what we see. So I think that is was very effective and it actually strengthened the relationship with administrators" (HRI, 2016).

HRI evaluators were not able to conduct analysis of project-based videos using the Determining the Quality of Mathematics Instruction protocol. HRI attempted to investigate the relationship between teachers' participation in the project professional development and leadership activities and their students' achievement scores using student data from the state assessment, however, the data for the participation pool was incomplete. HRI prepared annual reports addressing all evaluation activities and findings, including a final summative report. Formative feedback was provided on a more frequent basis through memos and videoconference presentations delivered to inform key project decisions and mid-course corrections, with regular contact via videoconference, phone, and email as appropriate.

DE K-12 Mathematics Partnership Project: Measures of Teacher Change:
Teacher Engagement & Professional Development Quality Perceptions

According to the Year 3 DE K-12 Mathematics Partnership Project summary report submitted by Horizon Research Inc., the professional development for elementary and secondary teachers and administrators was well received. Teachers, for the most part were very satisfied with the quality of the professional development, with the more experienced participants responding most positively to items about the effectiveness of the professional development and its quality. In the elementary strands of the project, EMTL, more than 80% of the teachers agreed or strongly agreed to every one of the six items of instructional quality matrix with coaches' rating nearly 100% in the agree or strong agree categories. Similar results were found in *New Normal*, with teachers in the 2nd and 4th cohort expressing close to 100% satisfaction with the content in the program. When given the opportunity to provide additional feedback about their experiences in professional development, teachers made references to future involvement with the program, and the desire to implement what they had learned in professional development into their practice. Evidence of teacher satisfaction were indicated these quotes from participating teachers:

"I loved being able to work on math problems with my peers. There sometimes may be a place that I got stuck on a problem and the conversation will help to keep me moving forward by exposing something that I hadn't seen and would not have seen if I didn't have the opportunity to discuss the problem out loud." [NN Cohort 1]

"I had fun working on math problems with other teachers and learning new ways to attack and teach concepts." [NN Cohort 2]

"I really enjoyed the pedagogical talks we had this year. It seems that instructional strategies and pedagogical moves have become a higher priority in the New Normal program this year, which has been great! Every teacher, no matter the content or grade level, can all relate and implement new pedagogy in their classrooms." [NN Cohort 3]

"Reading and sharing ideas related to Crucial Conversations has been helpful. This book demonstrates strategies for resolving conflict. The notion of "rough draft talk" has enabled my students to speak up and be heard in a non-threatening environment. Working with my math coach has helped me to maintain my focus and gain confidence." [NN Cohort 4]

"The grade-level meetings were particularly effective for me. It was during these meetings that I gained specific content knowledge that I brought back to my students." [EMTL Group 1]

"Loved the ON-LEVEL time to talk to other teachers about learning sequences and hands- on level conversation." [EMTL Group 1]

"This experience has been wonderful in helping me to build confidence in teaching math in my class." [EMTL Group 2].

Teachers' Changes in Instructional Practice: Sets of related questionnaire items addressing teachers' frequency of practices were combined to create five composite variables, which were considered to be more reliable than individual survey items. Teacher responses signaled a significant increase in the frequency of planning practices, instructional practices, and student use of practices addressed in the professional development during participants' instruction for the years of engagement in the professional development compared to the previous academic

year. When asked if and how they anticipated their classroom practices changed as a result of their project experiences, nearly all teachers anticipated changes to their planning, classroom instruction, and routines. While the majority mentioned general changes using strategies learned, several teacher responses specifically referenced a shift toward student-centered instruction, increased focus on class discussions, opportunities for students to make claims, time for students to grapple/productively struggle with concepts, and the use of learning sequences. As examples, teachers wrote:

• Students will make more claims and more opportunities to prove or disprove their work during math instruction.

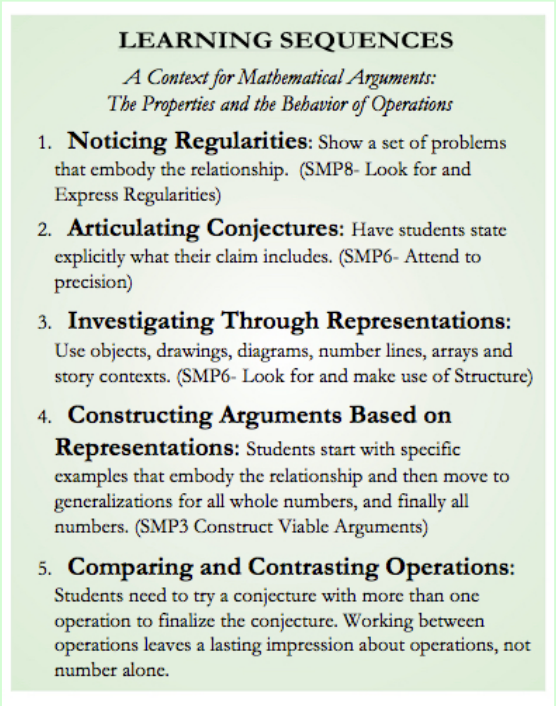
• I will allow my students to grapple and persevere more in class without jumping in for the rescue.

•I anticipate the use of talking points and learning sequence will help to generate better math discussions and provide opportunities for students to take the role as the teacher.

Teachers indicated many other anticipated changes including, but not limited to: teacher noticing, using investigative problems, and going deeper with fewer problems. Many teachers reported feeling more confident to talk to peers about mathematics instruction.

DE K-12 Mathematics Partnership Project: Measures of Teacher Change:
Assessment of Elementary Math Teacher Leaders' Content Knowledge

For the first ten years of the *Elementary Math Teacher Leadership* (EMTL) Program, facilitators used the nationally-normed teacher content knowledge test, *Measuring Knowledge for Teaching* (MKT) to assess participants' content knowledge growth. The test was selected as a result of the research documenting links to student achievement[1]. However, during the final year of the **DE K-12 Mathematics Partnership Project**, the leaders of the professional development recognized that the test was less suited to teachers' efforts for multiple reasons: 1) The project team facilitators were implementing a new targeted course of study that was based on the development of numeric reasoning, argumentation, and making claims, 2) The MKT did not include sufficient items to measure the nature of this specific focus, and 3) Some of our teachers had taken versions of the assessment across so many years that there appeared to be a ceiling effect.



LEARNING SEQUENCES

A Context for Mathematical Arguments:
The Properties and the Behavior of Operations

1. **Noticing Regularities**: Show a set of problems that embody the relationship. (SMP8- Look for and Express Regularities)
2. **Articulating Conjectures**: Have students state explicitly what their claim includes. (SMP6- Attend to precision)
3. **Investigating Through Representations**: Use objects, drawings, diagrams, number lines, arrays and story contexts. (SMP6- Look for and make use of Structure)
4. **Constructing Arguments Based on Representations**: Students start with specific examples that embody the relationship and then move to generalizations for all whole numbers, and finally all numbers. (SMP3 Construct Viable Arguments)
5. **Comparing and Contrasting Operations**: Students need to try a conjecture with more than one operation to finalize the conjecture. Working between operations leaves a lasting impression about operations, not number alone.

Studying Learning Sequences: During the final year and a half of the **DE K-12 Mathematics Partnership Project**, the *EMT*L leadership team chose to develop a course of study based on the book, *Connecting Arithmetic to Algebra*, (Russell, Shifter, Bastable, 2011). Under the guidance of Virginia Bastable, an author and researcher, the professional development team followed the book's trajectory, working with groups of teachers to investigate students' early algebraic thinking and tying together learning representations, connections, and generalizations to the study of number and operations in the elementary school grades. Using the same authors' pre-published learning sequences[2], teachers learned to pay attention to students' explicit remarks about regularities in the number system; they used lessons designed and organized to bring attention to such regularities and to support the students in using story problems, representations, and symbolic reasoning to articulate claims. The team also used *Making Number Talks Matter*[3]as a resource for promoting reasoning about the nature of number and operations, use of representations-based argumentation, and deeper understanding about strategies related to the commutative, associative, and distribute properties.

Developing our own Elementary Content Knowledge Pre-Post Assessment: To determine whether EMTL teachers were becoming more attentive to these elements of content reasoning, making claims, and representation-based argumentation, project leaders designed a series of pre-test items to be given at the opening of each EMTL session, prior to teaching the day's specific operation-based learning sequence. This pre-test structure was beneficial for many reasons: 1) It enabled a more productive start to the learning year, allowing EMTL leaders to

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[1] Hill, Heather C., Brian Rowan, and Deborah Loewenberg Ball. "Effects of teachers' mathematical knowledge for teaching on student achievement." *American educational research journal* 42.2 (2005): 371-406).
[2] Russell, Susan Jo, Schifter, Deborah, Kasman, Reva, Bastable, Virginia, and Higgins, Traci. (Forthcoming). *Mathematical argument in the elementary classroom*. Portsmouth, NH: Heinemann.
[3] Humphreys, Cathy, and Ruth Parker. *Making Number Talks Matter: Developing Mathematical Practices and Deepening Understanding, Grades 4-10*. Stenhouse Publishers, 2015.

spend the first full day of our course teaching new content and building community as opposed to monitoring a pre-test that often felt discouraging to the new teachers in the program; this reduced teachers' pre-test fatigue and gave the leadership team more accurate insight into teachers' specific strengths and weaknesses, 3) Writing pre-test items during the planning process helped EMTL facilitators to clearly identify the goals of the learning session, and 4) At the end of the day teachers and facilitators were more aware of their own success and growth towards the learning goal for the day.

Identifying Learning Goals: During each of sessions across the year, EMTL participants studied one of the four number operations with a focus on specific computational strategies and number properties underlying the use of these strategies. Facilitators modeled entire learning sequences, helping teachers to experience the process, and developing teachers' understandings of representations-based argumentation. For many of these teachers, this appeared to be the first time they were challenged to move beyond the use of examples to the use of generalization. For example, many teachers recognized "doubling and halving" as a strategy that may be efficient for multiplying two numbers mentally. However, did they learn how to connect this strategy to the associative property? Could they make a visual representation, a symbolic rule, and/or a story that exemplifies the "action" involved in the use of the associative property? The project team was committed to the development of a set of understandings that mirrored the algebraic *habits of mind* expected of mathematics students in more advanced grade levels.

Pre-test Item Related to Making A Claim About Doubling & Halving:

1. Jimmy made a conjecture about multiplication; he stated that if you double one factor and halve the other factor, the product does not change. Draw a model below to support this conjecture.
2. Which of these examples illustrates Jimmy's conjecture (above)? Circle all that apply.

(A) $a \times b = (a \times 2) + (b \times ½)$

(B) $14 \times 25 = 7 \times 2 \times 25$
$(7 \times 2) \times 25 = 7 \times (2 \times 25)$
$7 \times 2 \times 25 = 7 \times 50$
$7 \times 50 = 350$

(C) $a \times (2 \times ½) \times b = a \times b$

(D) $(a \times b) \times c = a \times (b \times c)$

3. Prove or disprove. Jimmy wondered if the same conjecture would work for division. How would you help students to examine this conjecture?

Scoring & Reliability: Before project leaders developed the post test, the four project facilitators met across the course of two days to review the pre-test results, to articulate the important learning objectives each item measured, and to develop a scoring rubric. After multiple rounds of scoring the items collaboratively, the team established reliability on the scoring rubric and completed scoring all items together. This scoring rubric was then in advance, in place for scoring the post-test items.

Findings from the Pre-Test: In the pre and post-tests, EMTL facilitators were explicit in requesting teachers to use multiple models such as story contexts, drawings, number lines, arrays, and generalized symbolic reasoning. The analysis of the pre-tests revealed that approximately 34% of the EMTL participants (21/62) proposed sharing examples as their *sole* strategy for developing reasoning and argumentation. Most of the teachers (59%) did not provide accurate representations, even when asked specifically to do so. Project leaders also observed that veteran EMTL teachers were more likely than their peers to support a conjecture with an algebraic generalization. Although pleased that they were able to do so, project leaders were intent on finding evidence that EMTL participants could utilize more student-accessible reasoning tools and produce more compelling representations-based arguments.

As part of the scoring criteria, project leaders developed item-specific rubrics related the use of visual models and the use of stories to support their reasoning. An initial inspection of the pre-test results revealed that teachers' struggled to develop stories, drawings, and models. For instance, in a pre-test question about steps for developing mathematical argumentation, approximately 21% of the teachers (13/62) could not come up with any ideas for supporting the development of reasoning and argumentation around a mathematical idea. Approximately 38% proposed to share examples as a strategy accompanied by one other strategy such as using a picture or model. Only 1% of the teachers (5/32) provided more than two steps beyond examples in their work for making and supporting conjectures. **In the pre-test the number of strategies for developing and supporting conjectures** cited across all 62 teachers totaled 79, and, more than half the group only cited examples.

Developing the Elementary Content Knowledge Post Test: In order to develop the post test, EMTL leaders re-examined the learning goals for the program and developed a post-test item matched to each of the pre-test items in the targeted categories to include: 1) articulating the steps of the learning sequence, 2) supporting the development of a mathematical conjecture using the steps of the learning sequence, 3) using multiple, student-appropriate representations and models to support a conjecture, 4) moving beyond the use of examples as the sole basis of argumentation, and 5) representing multiple student strategies with appropriate models. In order to have a complete set of pre-post matching items, we collected data from teachers who attended all of the sessions throughout the school year, comparing the pre-post performance.

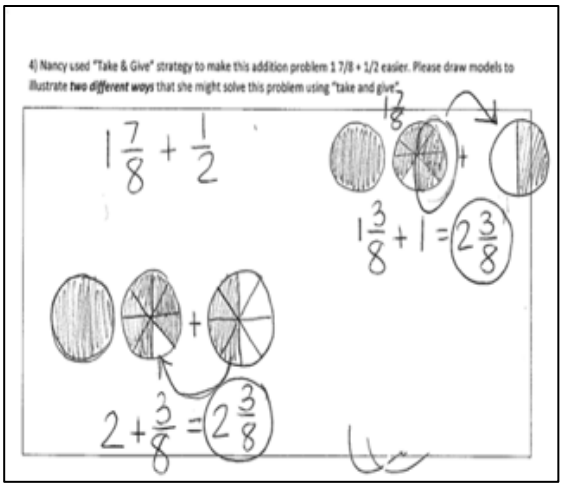
Sample Post-test Items (Formatting removed)

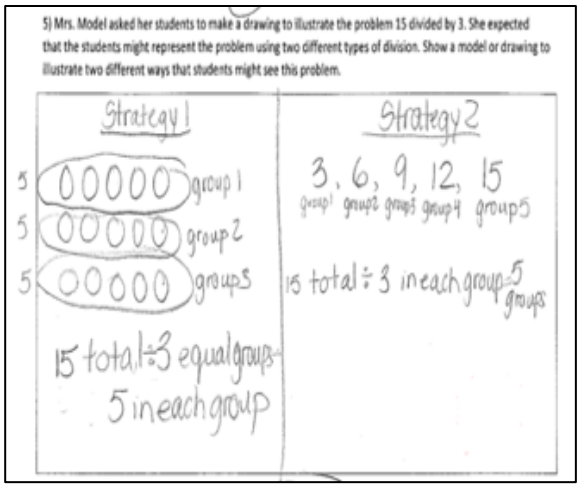
1. Jimmy made a conjecture about multiplication; he stated that if you double one factor and halve the other factor, the product does not change. **Draw a model below to support this conjecture and then write the algebraic notation.**
2. Jimmy wondered if the same conjecture would work for division. Jerry shared this example:
   24 ÷ 3 does not equal 12 ÷6. **Write a story context that shows why halving and doubling doesn't work for division.**
3. Jan used all the steps of the Learning Sequence to help students learn the commutative property. Please describe, using examples and illustrations, the way in which she would teach the lesson.
4. Nancy used "Take & Give" strategy to make this addition problem 1 7/8 + 1/2 easier. Please draw models to illustrate ***two different ways*** that she might solve this problem using "take and give".
5. Mrs. Model asked her students to make a drawing to illustrate the problem 15 divided by 3. She expected that the students might represent the problem using two different types of division. Show a model or drawing to illustrate two different ways that students might see this problem.
6. Joey made a claim about addition. He said that if you increase either addend by any number, you will increase the sum of that addition problem by that same number. Another student asked if this claim works for subtraction as well. **Prove or disprove the second student's conjecture about subtraction.**

Post-test Results: At the end of the year, the analysis of the post-test results demonstrated that 81% of the teachers could successfully describe how to develop students' ability to make and support conjectures using 3 or more steps of a learning sequence. The area in which the teachers showed the most growth was in moving beyond the sole use of examples as a means to develop and support a conjecture. There was also an across-the-board increase in the use of models, visual representations, and the use of generalizations to support conjectures. Project leaders gained valuable insights about the ways in which EMTL teachers became more proficient in making generalizations and supporting conjectures, and in areas in which they still need to improve (developing story problems and drawing appropriate visual representations).

Project leaders did not necessarily anticipate that EMTL teachers would become much more proficient in their use of generalized symbolic reasoning. Although the facilitators encouraged the teachers to use representations-based argumentation and visual models, the teachers quickly became more confident in their use of symbols and algebraic representation, often to the detriment of the use of more student-appropriate methods.

The following examples from the post-test illustrate the teachers' post-test approaches to developing representations and illustrations of number operations and properties. Noticing regularities, developing and articulating conjectures about number, and then supporting these conjectures with representations that included stories, generalizations, and visual "proofs" are evidenced.





We attributed teachers' content knowledge growth to the use of the learning sequence instruction. Teachers were better able to describe potential ways to develop a representation-based argument and could describe how they would teach these strategies to their own students. This is evidenced in the example provided on the right. In the post tests **the number of strategies proposed for developing and supporting conjectures** presented across all 62 teachers increased to 224 as compared to 79 in the pre-test.

Statistical Significance

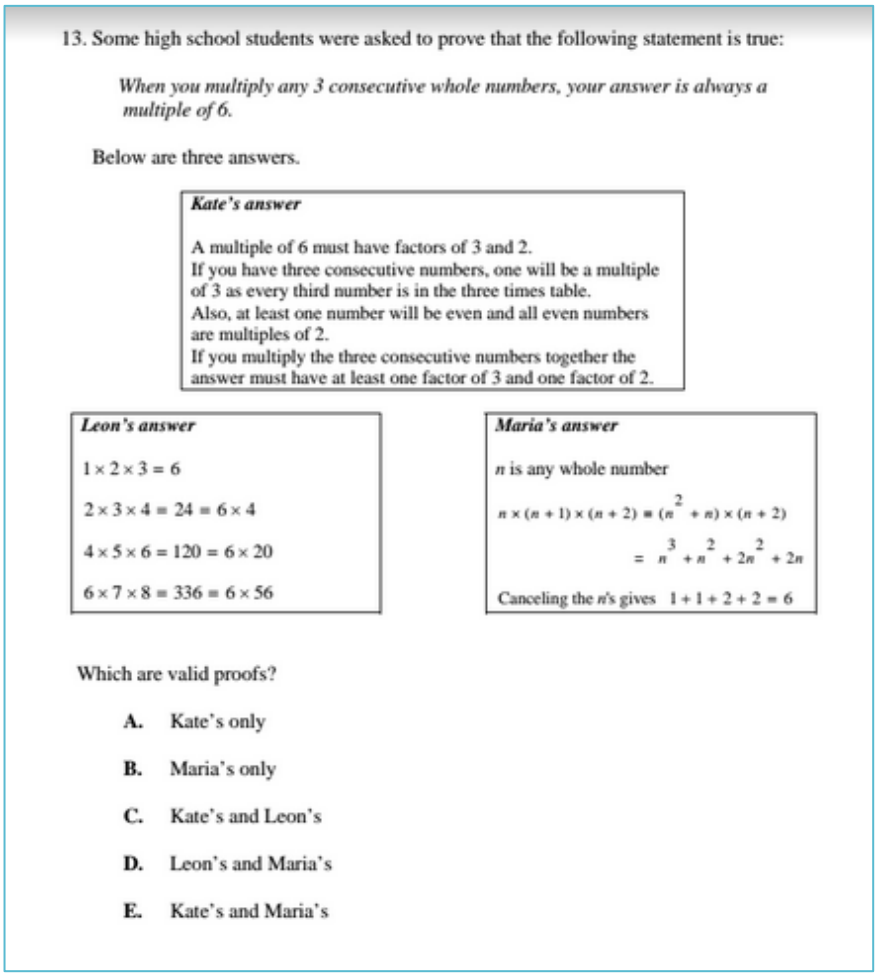
The teachers who were in attendance for all of the pre-test questions (n=62) were compared in a pre-post matched t-test and determined that the growth was statistically significant ($p < .01$). In the post-test there was an across-the-board increase in the use of models, visual representations, and the use of generalizations to support conjectures. Project leaders gained valuable information about the teachers' thinking and areas in which they still need to improve (developing story problems and drawing appropriate visual representations).

DE K-12 Mathematics Partnership Project: Measures of Teacher Change:
Assessment of New Normal Teachers' Content Knowledge

Past efforts to assess the content knowledge growth of teachers' participating in the Delaware Mathematics Coalition's secondary professional development programs were met with both successes and challenges. While leaders of the **DE K-12 Mathematics Partnership Project** were pleased with the problem-based nature and level of rigor of their past assessments, we questioned whether a single assessment could effectively gauge the impact of the different content-focused experiences in the successive strands of the *New Normal* program. Project leaders were also concerned about a perceived ceiling effect for long-term participants in the professional development.

In the final year-and-a-half of the **DE K-12 Mathematics Partnership Project**, project leaders collaborated with Dan Heck, a lead researcher at Horizon Research Inc. (HRI) to identify norm-referenced assessments that could potentially be used to measure the content knowledge growth of teachers' participating in the *New Normal* cohort-based courses-of-study. After comparing the learning targets for the progressive content-focused strands and the items on the assessments, project leaders selected the following norm-referenced and project-based tools to assess the content knowledge growth of the teachers in *New Normal* professional development program:

- *Knowledge of Algebra Teaching* assessment o*r KAT* was developed by R.E. Floder, J. Ferrini Mundy, S.Senk, M. Reckase, R. McCrory with further support from the national Science Foundation (REC 0337595). The assessment included items that were specifically designed to measure teachers' pedagogical content knowledge and incorporated questions related to generalization and proof, a key focus in the *New Normal Cohort 1* and *Cohort 4* courses-of-study.



13. Some high school students were asked to prove that the following statement is true:

When you multiply any 3 consecutive whole numbers, your answer is always a multiple of 6.

Below are three answers.

Kate's answer

A multiple of 6 must have factors of 3 and 2.
If you have three consecutive numbers, one will be a multiple of 3 as every third number is in the three times table.
Also, at least one number will be even and all even numbers are multiples of 2.
If you multiply the three consecutive numbers together the answer must have at least one factor of 3 and one factor of 2.

Leon's answer

$1 \times 2 \times 3 = 6$

$2 \times 3 \times 4 = 24 = 6 \times 4$

$4 \times 5 \times 6 = 120 = 6 \times 20$

$6 \times 7 \times 8 = 336 = 6 \times 56$

Maria's answer

n is any whole number

$n \times (n+1) \times (n+2) = (n^2 + n) \times (n+2)$

$= n^3 + n^2 + 2n^2 + 2n$

Canceling the n's gives $1 + 1 + 2 + 2 = 6$

Which are valid proofs?

A. Kate's only

B. Maria's only

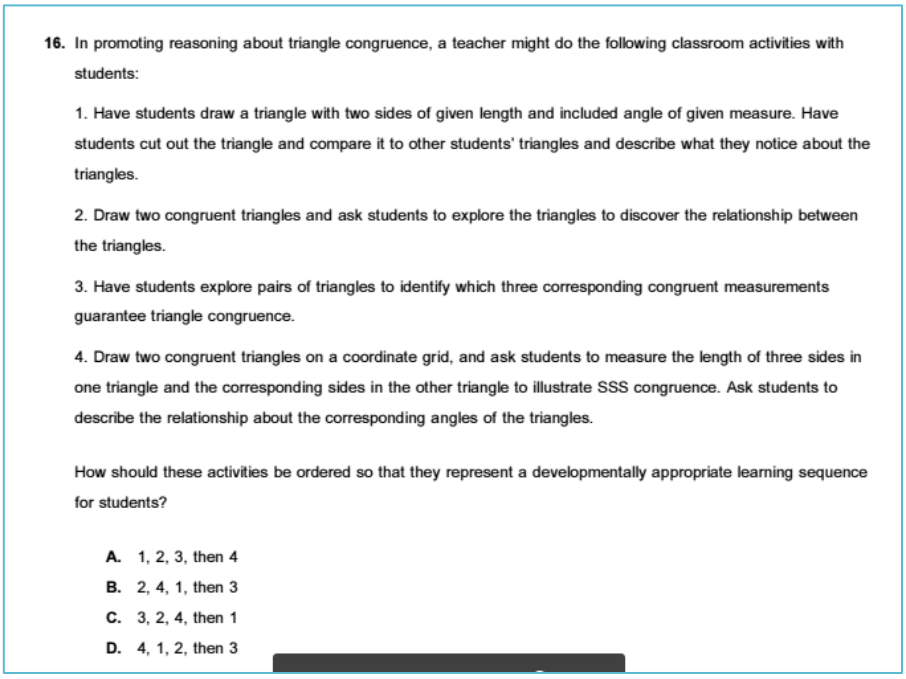
C. Kate's and Leon's

D. Leon's and Maria's

E. Kate's and Maria's

Sample Item from KAT Assessment

- *Geometry Assessment for Secondary Teachers (GAST)* was developed by researchers at the University of Louisville with grant funding from the National Science Foundation. The *GAST* project developed and validated assessments of secondary mathematics teachers' knowledge for teaching geometry. HRI evaluated the quality of the development and validation process as well as the quality and utility of the assessment. This assessment was used as the basis for our *New Normal Cohort 2* pre and post-test.



16. In promoting reasoning about triangle congruence, a teacher might do the following classroom activities with students:

1. Have students draw a triangle with two sides of given length and included angle of given measure. Have students cut out the triangle and compare it to other students' triangles and describe what they notice about the triangles.

2. Draw two congruent triangles and ask students to explore the triangles to discover the relationship between the triangles.

3. Have students explore pairs of triangles to identify which three corresponding congruent measurements guarantee triangle congruence.

4. Draw two congruent triangles on a coordinate grid, and ask students to measure the length of three sides in one triangle and the corresponding sides in the other triangle to illustrate SSS congruence. Ask students to describe the relationship about the corresponding angles of the triangles.

How should these activities be ordered so that they represent a developmentally appropriate learning sequence for students?

A. 1, 2, 3, then 4
B. 2, 4, 1, then 3
C. 3, 2, 4, then 1
D. 4, 1, 2, then 3

Sample Item from GAST

- *Project-Based Statistics Assessment was developed by members of the leadership and facilitation team for the New Normal Cohort 3 strand. The assessment was specifically designed to assess the course-of-study* emphasis, "reasoning, justification and generalization in the context of statistics and probability." The mathematical foci, consistent with the *Common Core State Standards for Mathematics* included:

  - Investigate chance processes and develop, use, and evaluate probability models.
  - Draw comparative inferences about two populations;
  - Investigate patterns of association in bivariate data;
  - Understand and evaluate random processes underlying statistical experiments and use probability to inform decision-making.

Sample item from Statistics Assessment:

Imagine that a new drug developed to treat a certain illness is undergoing tests and that a higher score on these tests indicates a more effective drug. After several trials, it is determined that the mean effectiveness of the new drug is 6.5 with a standard deviation of 1.5. This compares to a mean effectiveness for the current treatment option of 5.8 with a standard deviation for the current treatment of 1.0. Can you conclude from these data that the new drug is more effective than the current drug? Please explain your reasoning.

Assessment of Teachers' Content Knowledge: To assess the relevant content knowledge of the learning targets in the *New Normal* Cohort 1-4 strands, project leaders administered a pre-assessment at the start of each of the professional development day. This pre-test structure was beneficial for a number of reasons:

1) It enabled a more productive start to the learning year, allowing *New Normal* facilitators to spend the first full day of our course teaching new content;
2) It reduced teachers' pre-test fatigue and gave the leadership team more accurate insight into teachers' specific strengths and weaknesses;
3) Selecting and writing pre-test items during the planning process helped *New Normal* facilitators to clearly identify the goals of the learning session; and
4) At the end of the day teachers and facilitators were more aware of their own success and growth towards the learning goal for the day.

On the final day of professional development (spring 2016), *New Normal* facilitators administered a post-test including the same or closely parallel items to attempt to measure growth in understanding of the core content.

Scoring & Reliability: To preserve anonymity and promote reliability for scoring the *New Normal* Cohort 1-4 assessments, project leaders assigned each teacher with a random number to be used on the cover page of their pre and post-tests. The schema was utilized to compare pre and post-test matched pairs. Project leaders then worked together to obtain iterator reliability. Rather than simply comparing group means on each of the assessments, project leaders chose to use a more powerful matched pairs analysis in which each teacher served as his or her own control. The resulting t-test analysis included a total of 78 matched pair comparisons from the four *New Normal* cohorts.

New Normal Pre & Post-Test Results: Participants who were in attendance for each of the professional development sessions across the year were compared using a one tail t-test. Statistically significant growth was documented for each of the four cohort groups. The results for each of the New Normal cohorts are shown below:

***New Normal Cohort 1* Pre & Post Results**: A total of twenty-three teachers completed both the pre-assessment and post-assessments for the *New Normal Cohort 1* course-of study. The results of the t-test indicate that the growth for participants in the strand was statistically significant ($p < 0.0029$) with significant gains demonstrated for five of the seven items on the assessment. Participants made the greatest gains in their ability to represent and analyze mathematical situations using algebraic reasoning and symbolic notation, use and connect mathematical representations, and analyze rate of change and identify connections between recursive and explicit generalizations.

***New Normal Cohort 2* Pre & Post Results**: Eighteen teachers completed both the pre-assessment and post-assessments for the *New Normal Cohort 2* course-of study. The results of the t-test indicate that the growth for participants in the strand was statistically significant ($p < 0.011$) with significant gains demonstrated for four of the five items on the assessment. Participants made the greatest gains in their ability to represent geometric relationships in multiple ways, recognize and accurately make basic transformations, and arithmetize and algebrafy geometric properties. While teachers made progress with regard to their ability to visualize geometric figures from a dynamic rather than static point of view, researchers found that participants were still not as likely to "think outside of the box" when it came to their exploration of geometric properties requiring a more dynamic perspective to solve tasks. This

leads us to believe that more extensive time with such tasks would be useful to the community.

***New Normal Cohort 3* Pre & Post Results**: A total of twenty-one teachers completed the pre-assessment and post-assessments for the *New Normal Cohort 3* course-of study. The assessment results were analyzed with regard to each of the learning targets:

- Assessment of Measures of Center and Variability: Twenty one teachers completed both the pre-assessment on our first day of PD and the post-test on the fifth day of PD. Eleven of these teachers showed a gain between pre- and post-test on this assessment, five teachers regressed on the post-test, and the balance, 5 teachers showed neither gain nor loss. Using a one-tailed matched pairs t-test (N=21), we found a significant effect (gain) at the p=0.1 level of significance (our test statistic was computed to be 0.0804). These results may have been slightly depressed by the fact that some of the items on the post-test were altered slightly. For example, on the day 1 assessment, respondents were to determine appropriate measures of center and spread for four different data displays including a "bar graph with categorical data." On the post-test, however, the qualifier "with categorical data" was omitted and this may have depressed scores accordingly.

- Assessment of Theoretical Probabilities for a Chain of Independent Events: Of the teachers who completed the post-test on the fifth day of PD, nineteen also completed the assessments on the second day of PD. Twelve of these teachers showed a gain between pre- and post-test on this assessment, four teachers showed neither gain nor loss, and only 3 teachers had (slightly) lower scores on the post-test. Using a one-tailed matched pairs t-test (N=19), we found a significant effect (gain) at the p=0.01 level of significance (our test statistic was computed to be 0.0068).

- Assessment of Inferential Statistics 1: Sample Size: Of the teachers who completed the post-test on the fifth day of PD, eighteen completed the pre-test on the third day of PD. Twelve of these teachers showed a gain between pre- and post-test, four teachers showed neither gain nor loss, and only 2 teachers had a lower score on this topic on the post-test. Using a one-tailed matched pairs t-test (N=18), we found a significant effect (gain) at the p=0.01 level of significance (our test statistic was computed to be 0.0077).

- Assessment of Inferential Statistics 2: Comparative Inferences about Two Populations given Means and Standard Deviations: Of the teachers who completed the post-test on the fifth day of PD, twenty completed the pre-test on the fourth day of PD. Eleven of these teachers showed a gain between pre- and post-test, three teachers showed neither gain nor loss, but six teachers had a lower score on this topic on the post-test. Using a one-tailed matched pairs t-test (N=20), we found no significant gain (or loss) on this topic (our test statistic was computed to be 0.4759). On a closer examination of both the pre- and post-test items and the rubric developed to score these items, it appears that the post-test version of the extended response item was significantly more ambiguous than the pre-test version and this may have accounted for the lack of significant effect.

In summary, on the four core topics assessed with the nearly two dozen *New Normal Cohort 3* teachers, significant gains in content knowledge were found using a matched-pairs design (teachers serving as their own controls) on three of the four content foci, and two of these areas showed significance at p= 0.01.

***New Normal Cohort 4* Pre & Post Results**: Sixteen teachers completed both the pre-assessment and post-assessments for the *New Normal Cohort 4* course-of study. The results

of the t-test indicate that the growth for participants in the strand was statistically significant ($p < 0.002$) with significant gains demonstrated for five of the seven items on the assessment. A comparison of outcomes for Cohorts 1 and 4 teachers suggests that long-term participants of the program did substantially better (higher pre and post-test means) than teachers who were new to the project. This leads us to believe that over time, participants' experiences may be positively correlated with greater gains in content knowledge growth.

DE K-12 Mathematics Partnership Project
Lessons Learned

During the 2014-2016 project period, the Delaware K-12 Mathematics Partnership Project was spearheaded by the Delaware Mathematics Coalition's (DMC) strategic planning team.

The DMC leadership engaged 19 district partners, 6 charter schools, Delaware DOE, leaders representing business, and mathematics faculty from three higher education institutes, in monthly conversations about mathematics practice, professional development, and policy. The professional development project, in addition to serving Delaware teachers, also fostered dialogue and connections between district and higher education partners and the DMC.

According to the project evaluation report by Horizon Research Institute the project delivered:

- A progressive course-of-study to address the evolving needs of teachers, coaches, and administrators in partnership schools;

- Sustained and recursive opportunities for participants to converge in cohort-based communities, focused on a common set of core content and pedagogical goals;

- A cohesive approach to promoting the actualization of problem-based CCSS-inspired teaching; and

- Multi-layered leadership strands aimed at increasing leadership and instructional capacity of teacher-leaders, coaches, and school/district administrators.

The evaluators concluded that:

- The PD for elementary and secondary teachers and administrators was well received and consistent with the framework for high-quality PD used by the evaluation team.

- Attention to all of the attributes of high-quality PD delineated in the framework was evident in interviews with project leaders and administrators from schools and districts that have been consistently involved in the PD programs.
- Project participants in the projects responded positively regarding the impacts of participating in the PD; comparisons across cohorts suggest that teachers in the more advanced cohorts report stronger outcomes than those in introductory cohorts.
- A significant increase in the frequency of planning practices, instructional practices, and student use of practices addressed in the PD was evident in participants' instruction for the years of engagement in the PD.

Content Cohorts: To address the varied needs of teachers, specialists, and administrators in the project, the leadership team organized the course-of-study offerings into a set of cohesive content-focused and pedagogically-grounded progressions. Based on teachers' previous experience in professional development, they were grouped together in subject level and experience-based teams; in some cases they were purposefully re-grouped during morning and afternoon segments of the day. Cohorts' content focus was grounded in conceptual understanding across all courses, progressing through number structure and base ten operations at the elementary level (EMTL) and targeted content in algebra, geometry, and statistics at the secondary level (New Normal). Problem solving was embedded in each cohort strand. Evidence from HRI suggested that this design-structure supported the varied needs of

the participants. Teachers expressed an appreciation and understanding of the pedagogical ideas emphasized in each of their cohorts.

Teacher Leadership: In the final year of the project, project leaders added a fourth cohort to the New Normal program. The inclusion of the leadership cohort was designed to target specific skills to leverage increased mathematics leadership capacity in their schools. Participants selected the cohort strand because of their expressed interest in playing a more central role in influencing and developing mathematically intense conversations with their colleagues. In the previous year we had established an after-school K-12 leadership cohort; however due to funding and an analysis of attendance patterns for our evening meetings, project leaders determined that many more teachers could be reached within the school-day structure. Daytime sessions included content-focused coaching and lesson analysis skills to enhance productive school collaboration. The group also engaged in a focused study of chapters in Patterson's Crucial Conversations book. Data from our evaluation surveys revealed that teachers were finding the inclusion of relational and dispositional skills to be of tremendous value to their daily roles as leaders in their schools. The decision to support even more focused time with the teacher leaders resulted in greater satisfaction and engagement for guiding the translation of learned skills and understandings to school-based enactment.

Growing Practitioner-Based Professional Development Capacity: Over the course of the 2.5 years of our project, a growing number of the teacher leaders became interested in becoming PD presenters, assumed roles as PLC leaders, and/or coaches of school or district-based teams. As the leadership group matured, a subset of the teachers and coaches were recruited to lead grade-level alike afternoon sessions in EMTL and segments in New Normal program. In EMTL, three of the long-term participants stepped up to facilitate afternoon grade level sessions. Another member of the group became a part of our project staff, facilitating AM content sessions and PM content sessions. All of these teachers, after considerable collaboration and coaching, became skilled in making insights that resonated with colleagues. Their expertise and enthusiasm has added energy and investment in the project.

School Based Support: During year 3 of the project, evaluators conducted case studies to determine how school structures in high concentration project schools develop. In the secondary school study, we learned that principals are thinking hard about how to apply what they learned through involvement in the community. One high school principal interviewed by HRI described how she intended to build on the New Normal professional development by involving a mathematics leadership team from her school. She stated that she envisioned that this leadership team, as a core group, would influence others, building on the foundation New Normal had established. Participating teachers from this school reported that their participation strongly impacted their comfort in implementing strategies they learned in the PD. (HRI, 2016).

The elementary case study conducted by HRI also revealed insights and perspective regarding the impact of the PD. The interviews revealed that having a critical mass of teachers involved in the project makes a difference, particularly when the assistant principal and mathematics specialist work with the teachers and focus their collective efforts on a given area of mathematics instruction. In the case of this elementary school, the teachers committed to implementing Number Talks in their classrooms. The school's broad participation resulted in a strong sense of investment and enthusiasm from all of the teachers in the school.

Adjustments in Assessment Strategies: Project leaders also changed our assessment practices during the final year of the project. Instead of administering a generic pre-test across all of the cohorts in both projects, facilitators designed 1-2 items to use at the start of each session based

on the day's content goals. Administering these items required a shorter time period during each session; this enabled facilitators to build a healthy culture right from the start and was less likely to overwhelm or discourage new teachers with a long pre-test. During each session, participants could document progress towards the learning goal, recognizing their progress in knowledge around the pre-test question. At the end of the project year, a comprehensive post-test was designed based on the goals of each session, using matching items. These assessments were more tightly aligned with the goals of the project and allowed us to gain more useful, formative insight into the effectiveness of the content-based sessions.

Addressing Challenges and Applying Findings:

• Participants continue to ask for more grade-level alike sessions. We will continue to structure opportunities for teachers to work in content-focused and grade-alike groups whenever possible.

• Because participants were finding it hard to influence peers who did not attend the professional development, we increased the number of leadership cohorts in an effort to provide teacher leaders with the disposition, skills, and confidence to develop collegial conversations. We also added staff "connectors" to our ongoing projects.

• Participants appreciate the use of video-based conversations. In future projects we plan to devote more effort to use a video-based analysis tool to as a means to develop more mathematically intense collegial conversations. Dr. James Hiebert and Dr. Dawn Berk will serve as thought partners for this work.

• As a result of our focus on leadership, a cadre of highly-skilled coaches, teacher-leaders, and teacher professional development facilitators have emerged; these leaders have a high degree of credibility with project leaders and with colleagues. They have also become more involved in making national presentations. During year two of the project, we noted that nearly twenty members of the project and project leadership team participated in presentations at NCTM and/or NCSM.

• Teacher facilitators have greatly enhanced the delivery of content-based, grade-alike sessions After many years of work with the project, they have become poised, knowledgeable presenters.

• Changes in assessment practice provided more information about teacher knowledge and needs; we believe we are providing more valid data collection and greater insight into the effectiveness of the content training.