INVERNESS RESEARCH

WHAT TEACHERS SAY ABOUT THE BENEFITS OF MAP CLASSROOM CHALLENGES

Introduction

The Math Assessment Project (MAP) is a collaborative effort between teams of mathematics educators from the Shell Center for Mathematical Education at the University of Nottingham and from the University of California, Berkeley. The goal of the Mathematics Assessment Project is to design and develop well-engineered, high-quality assessment tools to support teachers and schools in implementing the Common Core State Standards for Mathematics (CCSSM). The Mathematics Assessment Project is developing 100 Classroom Challenges (CCs) to be used in middle and high school math classrooms, which are available to teachers to download free of charge for non-commercial use from the MAP website.[1]

Also known as "formative assessment lessons" (FALs), the MAP Classroom Challenges are unique hybrids that incorporate elements of mathematical investigations, lessons, assessments, and cooperative group collaborations. Classroom Challenges are of two types. Concept Development Lessons, according to the MAP website, "are designed to reveal and develop students' conceptions, and misconceptions, of significant mathematical ideas and how these connect to their other knowledge." Problem Solving Lessons are "designed to assess and develop students' capacity to apply their mathematics flexibly to non-routine unstructured problems, both from the real world and within pure mathematics." Both types of lessons are grounded in the content and "mathematical practices" proposed in the CCSSM.

As part of the development of the Classroom Challenges, MAP selected teachers in three states—California, Michigan, and Rhode Island—to pilot early versions with their students. The teachers were asked to implement the CCs in their classrooms. They and a small cadre of MAP observers, who provided detailed descriptions of each lesson, then gave in-depth feedback to the developers to aid in the revision and refinement process.

The Mathematics Assessment Project team invited Inverness Research to help portray the MAP Classroom Challenges and to make them known to a spectrum of potential users, educators at all levels of the system interested in realizing the vision of the CCSSM in their local settings. As part of that effort, Inverness Research conducted in-depth interviews with 12 of the pilot teachers in July 2012. All 12 teachers piloted at least 5 Classroom Challenges, and many used as many as 25 over a two- to three-year period. This report presents the findings gleaned from those conversations.

Central to the following discussion are the teachers' experiences of actually using and reflecting on the Classroom Challenges in their classrooms, as well as their reports about a range of benefits

[1] http://map.mathshell.org

they attribute to using the CCs. Their overall experiences were overwhelmingly positive, contributing, as they told us, to growth and development in key dimensions of change: their thinking about their subject matter, their knowledge of pedagogy, their actual classroom practice, and their students' mathematical capacity.

This report is organized in sections, each of which describes in detail the benefits to teachers of using Classroom Challenges.

I. MAP Classroom Challenges Help Fulfill the Vision of the CCSSM

1. Using CCs helps teachers enact the CCSSM.
2. CCs feature and promote the process skills described in the CCSSM.
3. CCs provide structures and strategies to teach mathematical concepts in depth as expected by the CCSSM.

II. MAP Classroom Challenges' Design Facilitates Teachers' Use

1. CCs are accessible and easy to use.
2. The CCs' design makes the use of formative assessment a reality in classrooms.
3. While designed to function primarily as formative assessments, CCs also succeed as high-quality lessons.

III. MAP Classroom Challenges Stimulate and Expand Teachers' Thinking

1. Using CCs rekindles teachers' appreciation and love of mathematics.
2. Teachers transform the way they think about the *nature* of mathematics as a result of using CCs.
3. Teachers change the way they view the teaching of mathematics.
4. Teachers learn about the essential qualities and value of formative assessment.

IV. MAP Classroom Challenges Enhance Teachers' Practice

1. Teachers say CCs make them better teachers.
2. Teachers make a fundamental shift from teacher-centered to student-centered practices.
3. Teachers become more aware of and deliberate about their interactions with students.
4. Teachers learn how to practice more active listening.
5. Teachers learn to pose questions aimed at furthering student thinking.
6. Teachers learn how to orchestrate and facilitate both small and large group work and discussions.
7. Teachers successfully implement the pedagogical strategies embedded in CCs in other areas of their practice.
8. Teachers model other math lessons on the basic design structure of the CCs.
9. Teachers learn to expect higher levels of intellectual engagement from all their students.

V. MAP Classroom Challenges Benefit Students

1. Students' thinking about the *nature* of mathematics transforms.
2. Students are more engaged in mathematics.
3. A broad range of students have access to the mathematics while engaged in a CC.
4. Students' mathematical understanding is enriched by the collaborative nature of CCs.
5. Students develop skills and attitudes that enable them to construct mathematical knowledge.

VI. In Conclusion

I. MAP Classroom Challenges Help Fulfill the Vision of the CCSSM

The Common Core State Standards are upon us. Districts, schools, and teachers across the country have accepted and often welcomed these new high-level standards aimed at achieving "greater focus and coherence" to mathematics education in the U.S. One of MAP's main goals in creating the Classroom Challenges is "to bring to life the Common Core State Standards in a way that will help teachers and their students turn their aspirations for achieving them into classroom realities." The aspirations of the teachers we interviewed were met.

1. Using Classroom Challenges helps teachers enact the CCSSM.

Overwhelmingly, the teachers we interviewed found the CCs very helpful in "exemplifying CCSSM in explicit down-to-earth performance terms." They were broadly prepared for the reality of CCSSM implementation. But experience told them that translating the standards to actual instruction would take not only time, but also a thorough rethinking of current curriculum and pedagogy. Any materials to support them in this process would be welcome, and teachers were pleased to find that Classroom Challenges provide just such aid. Because CCs exemplify the kind of content and higher order thinking skills the CCSSM espouse, when pilot teachers used them regularly with students they brought the standards to life in their classrooms.

> ***The MAP Classroom Challenges are all aligned to the Common Core. Each one is a complete lesson incorporating 21st century skills to teach and assess concepts and content that engage students. They really get your students thinking.*** [2]

2. CCs feature and promote the process skills described in the CCSSM.

By virtue of their design, CCs require students to employ mathematical processes that purposefully mirror those articulated in the CCSSM. CCSSM "Mathematical Practices" are those deemed critical for mathematical proficiency. They include broad categories such as problem solving, reasoning, and communication, as well as eight specific practices that include "Make sense of problems and persevere in solving them," "Construct viable arguments and critique the reasoning of others," and "Model with mathematics." Teachers reported that MAP CCs provide multiple opportunities for them to teach and for their students to use these skills and practices.

> ***Do I feel like they will help me teach what is expected from the Common Core? Absolutely. My understanding of the Common Core is that there is much higher expectation around reasoning and problem solving, and the kids will be assessed on those skills. These lessons teach those skills in addition to the content.***

3. Classroom Challenges provide structures and strategies to teach mathematical concepts in depth as expected by the CCSSM.

Teachers told us one of the many benefits of Classroom Challenges is that they focus on one topic in depth. The standards address and try to remedy an issue prevalent in many classrooms today:

[2] Quotes are taken from transcripts of teacher interviews. In some cases they have been edited for brevity or readability but the intention of the teachers' words has been maintained.

curriculum that is "a mile wide and an inch deep." Teachers recognize this problem, and yet current instructional mandates often require them to focus on coverage of a vast number of topics per grade level. In contrast, a goal of the CCSSM is to increase students' depth of knowledge. The CCs helped teachers with this alternative approach: examining a concept closely, thoroughly, and iteratively over time with students.

II. MAP Classroom Challenges' Design Facilitates Teachers' Use

Throughout our interviews teachers commented on the high quality of the design of the Classroom Challenges. They used words such as "exemplary" or "superior" to describe the way CCs were written. They reported that even though CCs are innovative, truly challenging (as they are intended to be), and above all unfamiliar to both teachers and students, they are still approachable. Teachers can implement them effectively, and students can comprehend them beneficially.

1. CCs are accessible and easy to use.

Teachers told us that although the task of enacting the CCSSM in their classrooms was daunting, CCs are relatively easy and ready to use. Teachers were appreciative of the work already done for them in each and every CC lesson. Their overall view was that the Classroom Challenges provided a complete and well-organized set of materials.

> ***I like the Classroom Challenges because they're already created. It's hard to be teacher, lesson designer, and evaluator, so the benefit to me is being able to use a lesson that is totally mapped out, with all of the materials. The CCs are all rolled up into one neat package.***

Teachers reported that there is significant planning time involved in teaching CCs. They recommended teachers read through the lessons carefully beforehand and work through the mathematics problems on their own in anticipation of the questions or dilemmas their students might face. But unanimously the teachers found it worthwhile and instructive preparation. It allowed them to see the overall scope and rationale behind each lesson and it highlighted common student dilemmas or misconceptions.

2. The CCs' design makes the use of formative assessment a reality in classrooms.

In the same way that the CCs enabled teachers to realize key elements of the CCSSM in their classrooms, they also enabled teachers to conduct genuine formative assessment, often for the first time. Prior to their experience with MAP CCs, many teachers conceptualized assessment in simplistic terms, as matter-of-fact, single responses to closed questions or problems. For many of the pilot teachers, formative assessment meant little more than "not summative" assessment.

> ***For me formative assessment was a word that was thrown around quite a bit in our staff meetings, and I always thought, "Well, I do that anyway." So in truth I didn't have a lot of formal experience with formative assessment before the Classroom Challenges ... so some of the things we did and what I learned through using them were real shocks to me ... I now know formative***

assessment is really finding out what students actually do know about a large quantity of information.

However, CCs are deliberately designed to reveal students' mathematical thinking through bookended activities. They begin with provocative questions and problems in the pre-assessment, move into a collaborative examination and discussion in small groups, and conclude with a final whole group debriefing. Teachers were both surprised and delighted to find the lessons' structures making students' understandings and misunderstandings readily apparent, providing a kind of before-and-after perspective in each lesson, and thus revealing important information to the teacher and to the students themselves. After using the CCs, teachers told us they learned how a well-designed formative assessment can have a real place in the everyday classroom.

3. While designed to function primarily as formative assessments, CCs also succeed as high-quality lessons.

Teachers further reported that Classroom Challenges are successful not only as formative assessment opportunities, but also as good math lessons. The primary source of their efficacy as lessons is their grounding in key pedagogical tenets that are, not coincidentally, championed by the CCSSM. Those that the pilot teachers highlighted include, but are not limited to, the focus on one mathematically rich topic, rather than many; the "open" rather than "closed" design of the CCs that makes them accessible to a range of students; the intrinsic demand for cooperation and communication among students; and the shift of responsibility and effort from the teacher to the student.

They are collaborative lessons that are built around one concept and they are structured so they allow an initial entry point that everyone can access in some way. They include multiple representations so that in a collaborative setting, you are allowing different people to see things in different ways.

Interestingly, while telling us about their value as lessons, teachers reiterated that they liked how the Classroom Challenges model the integration of formative assessment. Teachers said they learned that conducting ongoing formative assessment in the context of regular instruction is much more effective than isolating the two.

III. MAP Classroom Challenges Stimulate and Expand Teachers' Thinking

In ways that were sometimes unexpected, teachers found that using the CC formative assessment lessons forced them into self-reflection, revealing insights about their own teaching and, in many cases, prompting changes in long-standing pedagogical habits and routines. This was a surprise for many. They anticipated the lessons would help them diagnose gaps in their students' learning or perhaps add a few more tools to their teaching "toolbox." They did not expect that using the Classroom Challenges would actually change their thinking. But piloting the CCs caused teachers to reconsider key elements of their practice in fundamental ways.

1. Using CCs rekindles teachers' appreciation and love of mathematics.

Many of the teachers we interviewed reported that they were reminded of "the beauty of mathematics" when they encountered the Classroom Challenges. While preparing to use the CCs, they typically tackled the math tasks themselves, and they were rewarded with an experience of wonderful, deep mathematics.

> ***The math is really rich and it made me think of things differently.***

Ironically, for a variety of reasons, classroom math teachers rarely have the opportunity to "do the math," to spend time trying to solve challenging mathematical problems, in other words, to immerse themselves in their own discipline. Engaging with the CCs allowed teachers to be mathematicians again. Not surprisingly, some of the teachers realized that their personal experience and excitement with the math often translated to what they did with students—to their enthusiasm presenting problems, to what they highlighted, to what they looked for in students' responses.

> ***The most valuable thing for me is to sit down with the problems themselves and do them before I even read through the guide. I try to think for myself—"What are the important mathematics and what are they trying to get at here?"***

2. Teachers transform the way they think about the *nature* of mathematics as a result of using CCs.

After interacting with CCs, teachers not only rediscovered their own passion for math, they began to conceptualize the discipline of mathematics differently. Many said that prior to using CCs, they thought of math as a fairly linear, rule-oriented discipline, grounded in content that was their responsibility to pass onto their students. However, using the CCs with their students expanded their thinking. In the Classroom Challenges, they saw math portrayed as a more dynamic and inquiry-based discipline, where mathematical knowledge is constructed by students, both individually and collectively.

3. Teachers change the way they view the teaching of mathematics.

As teachers changed their perceptions about their chosen discipline, their conceptualization of how to teach it changed too. Teachers' fundamental views about teaching math often expanded as a result of implementing the pedagogies embedded within the Classroom Challenges. In particular when they observed their students' responses to the CC activities, teachers saw how students needed and thrived on relevant and rich problems, expressed their knowledge in multiple ways, and stepped up to taking responsibility for their own mathematical learning.

> ***It really has opened my eyes to the way that I teach math and to the way that the students learn.***

For many, this manifested in a profound reconsideration of their role in the math classroom. Teachers told us that exposure to CCs showed them that their earlier teaching mirrored their prior conception of the discipline: a teacher-driven dissemination of linear and discrete information. They described structuring lessons formulaically and maintaining tight control over the classroom.

In contrast to a classroom where the teacher is the "sage on the stage" and holds all authority, the CCs offered teachers a new role, one of orchestrating, guiding, and coaching students' learning experiences. The CCs encourage teachers to listen carefully, pose questions, and to facilitate (rather than to control) group discussions to develop mathematical understanding. As they learned and practiced these new roles and pedagogies via the CCs, their ideas about what constitutes good math teaching were reshaped.

> ***What I have started to realize as I use the CCs is that in the past when I was teaching it was easy for me, because I was comfortable and in control. My attitude was "This is how we are going to do things and this is how we do it, and if you just follow me, everything is going to be perfect." Since teaching these Classroom Challenges I have moved away from that. In the past whenever we had faculty discussions about the discovery approach, as in "you go and let students discover," that was always code for me. It was code for "not teaching." But these lessons have shown me how you actually can let students discover, that as a teacher you can allow students to open up more, to discuss more. This experience opened my eyes.***

Ultimately the Classroom Challenges helped teachers to become more attuned to their students, thereby revealing how mathematics teaching can be a constructive effort, involving teacher and student in an iterative, reciprocal relationship. The lessons make visible how students approach a problem, how they use and apply their knowledge, and how they work in groups.

> ***The independent work at the beginning of each Challenge is important for me because it allows me to be able to see where they are coming from: what they know and what they don't. It is also a good opportunity to see which students don't mind the initial struggle, and which ones get really frustrated and shut down and wonder what they are supposed to do. It all helped me to know them and their thinking.***

All of this helped teachers gain a more comprehensive picture of their students and enabled them to think in more nuanced ways about how their teaching could better support student learning.

> ***With these lessons I see more clearly how students are developing their knowledge of math. Rather than focusing just on what they know, I started to ask myself what tools they were learning, and what they were building, and how I could add to what they already knew. I wondered how I could give them more tools to continue to build their knowledge.***

4. Teachers learn about the essential qualities and value of formative assessment.

Again, teachers told us that they often didn't have a clear understanding of formative assessment before using Classroom Challenges. But by using CCs over time they gained a much more accurate, sophisticated, and nuanced view of formative assessment. They learned that formative assessment done well illuminates students' thinking and knowledge at critical junctures in their learning process, which in turn allows teachers to adapt their teaching to better meet specific needs in their classrooms.

> ***Formative assessment is really finding out what students actually do know. Before using the CCs what I aimed for was having students do what I did accurately. If we were solving equations I wanted them to be able to do what I showed them. It was easy to walk away thinking, "They are***

really good at this and they really understand it." But in fact what was really going on was that they were just mimicking me. Now I have a better understanding that there is a lot more information that we as teachers can look for, like having students recall previous knowledge and figuring out what they are struggling with, what they need to work on, and what they are already good at.

Teachers' new understanding of formative assessment fit well with their new conceptualization of mathematics and their role in teaching it. They saw how authentic formative assessment—that actually informs both teacher instruction and student comprehension—is instrumental to creating the rich, constructivist-based learning environment espoused by the CCs and CCSSM.

The Classroom Challenges involve a cycle of instruction, reflection, and further instruction based on both. It's not just, "Okay, here is the lesson, here is the test, now move onto the next one." With the CCs the teacher considers: What have my students mastered? What are they still questioning? Where is their confusion, and what are they understanding or not understanding?

IV. MAP Classroom Challenges Enhance Teachers' Practice

It is a truth universally acknowledged that if we can change teachers' minds, we can change their practice. In fact transforming thinking is the aim of almost all educational improvement efforts, a goal successfully realized by the MAP Classroom Challenges for its pilot teachers. Many of the teachers told us that when they re-conceptualized the nature of the discipline of mathematics, and when they also re-conceptualized the nature of mathematics teaching, they were compelled to change their practice, almost immediately.

1. Teachers say CCs make them better teachers.

"I have changed the way I teach because of these lessons" was a sentiment heard repeatedly in our interviews. Teachers found that the MAP lessons were of such high quality—mathematically and pedagogically—that simply doing them regularly helped to elevate their practice. The CCs modeled, both implicitly and explicitly, ways to improve what they did in their classrooms.

They made me a better teacher, in addition to promoting all sorts of mathematics with my students. The experience of using these lessons has been professional development in and of itself. They have taught me how to teach in far richer ways than I previously was doing. I got my National Board certification this year and I actually wrote about the Classroom Challenges as one of the things that most shaped my teaching in the last five years.

2. Teachers make a fundamental shift from teacher-centered to student-centered practices.

Of all the changes in their practice that teachers reported to us, one of the most important was a fundamental shift from a teacher-centered to a student-centered orientation. Many said it wasn't easy. In fact, it was often more challenging to employ a less teacher-centered approach. Teachers

had to take a risk, to give up control and to be more deliberate about their interactions with students. But teachers also found that when they removed themselves as the primary presence and authority in the classroom, students became more engaged in and responsible for their own work in mathematics.

Several teachers noticed that in their teacher-centric classrooms, they had unwittingly made students dependent on them, and in the process had placed a premium on getting "right" answers with little emphasis on deep conceptual understanding. "I didn't realize how much of an enabler I was," said one teacher. With the Classroom Challenges teachers took on the new roles—observing students' work and conversations, and coaching through offering encouragement or posing questions—thereby placing students at the center of the classroom learning.

> ***I see that when my students are working without my instruction, without my direction, they can actually do it. I realize I don't have to do everything for them; they are able to do things independently. It's also nice just to watch. I roam around the room and make observations about what they are doing and what is interesting about their work.***

3. Teachers become more aware of and deliberate about their interactions with students.

The design of Classroom Challenges demands that students do more of their own mathematical thinking and problem solving. At the beginning, teachers said, "letting go" was challenging. As one attested, "I always had a fear of letting them fail." But, as teachers increased their use of CCs they began to slow down, to become more thoughtful about and to privilege the interactions they had with students.

> ***Before, I had 30 kids in the classroom, and each would check in with me—"Is this right?" and I would say, "Yeah, yeah, that is good," and move onto the next kid. They didn't necessarily know why it was the right answer and they really didn't have a concept of what they were doing or why they were doing it. Piloting these lessons taught me to ask instead—"What do you think? Why do you think that is right?" I've learned to slow down a little bit and have that discussion with them.***

Several teachers told us that they recognized that letting students "sit with" a question or problem, pushing through confusions and mistakes, would benefit them in the long term.

> ***I am much better at slowing down and waiting for kids to think.***

This teacher and others began to see the value of deliberately orchestrating these kinds of interactions. At first glance, a teacher may seem passive in this role, not practicing "direct instruction" as is so often mandated in current schools and districts. However, the observing, the pausing, and the posing of open-ended questions reflect proactive choices the pilot teachers began to make in their classrooms in order to fulfill the goal of learning from their students' thinking to adjust and improve the teaching and learning process.

> ***I learned that I need to be able to give my students the message that it is okay to struggle with math, that it's okay to struggle with anything, and that is part of the learning process. It doesn't mean that you are failing and it doesn't mean that you are not going to learn. But you actually***

have to give them permission for that and that is really big. When they are confused, it is tough for me to stand back sometimes, but the Classroom Challenges encourage me to do so.

4. Teachers learn how to practice more active listening.

I learned the importance of walking around and observing a group without interfering. That is hard for me as a teacher because I have things to say, but learning to shut up is really important.

Teachers learned from the CCs that by practicing active listening they also learn important information about how their students are thinking mathematically. They hear about what confuses them and what they understand. In turn teachers told us they used this information to adjust their lesson plans—to re-visit a concept, to make changes in student seating configurations, or to move forward quickly. Equally significant, we learned that with less frequent interjections by the teacher, and with more active listening and interest, students naturally begin to take responsibility for constructing their own knowledge, individually and with their peers. Students develop confidence and voice.

5. Teachers learn how to pose questions aimed at furthering student thinking.

Many of the teachers said that before experiencing the CCs, their classroom questioning strategies consisted of right or wrong answer questions. Beyond that limited, closed design repertoire, they felt at a loss about what to ask students to further their thinking. But good, open-ended questions are embedded into the CC guide, and teachers relied on them. They told us that over time, they gained a sense of what kinds of questions generate student responses, learning where to pitch a question to advance a student's thinking in just the appropriate way.

6. Teachers learn how to orchestrate and facilitate both small and large group work and discussions.

Again, the Classroom Challenges' thoughtful design became a model for teachers as they expanded their pedagogical repertoire. Each CC presents multiple opportunities for paired, small and whole group work, and by following the lead of the lessons, teachers learned to facilitate the different types. Prior to their CC experience some said they were unsure of how to use group work effectively and they didn't usually consider the respective value of different sized groups when planning. After using the CCs, teachers understood when it is important to work in small groups, when to bring the whole group together, and what kind of task is most appropriate in each setting.

Because the teacher's guide is well designed and scripted, it has helped me see the steps along the way—what I would ask, what I would do, or where I would stop the small groups and have a discussion. I feel like using these has really taught me the elements that need to go into a rich problem-solving lesson. Before I used the CCs I just didn't really know how to do it. I thought, kids work on these problems and then what? How do I pull it together? I never really knew how. So these have taught me how to pull it together and, in particular, how to lead a whole class discussion.

7. Teachers successfully implement the pedagogical strategies embedded in CCs in other areas of their practice.

Teachers began to use many of the pedagogical strategies they had learned from the CCs in their other lessons. After their firsthand experiences of the value of strategies such as more purposeful questioning, active listening, and small and large group facilitation, teachers began to internalize these strategies and apply them to additional teaching contexts. They told us their questioning style changed to include more pauses and more follow-up queries such as, “Why do you believe that is true?” They said they listened differently to their students' responses and ideas and made instructional decisions based on them, and less on the need to tackle the next topic. They adopted more of a background role so more student-to-student interactions could take place, and they facilitated better whole class debriefings.

8. Teachers model other math lessons on the basic design structure of the CCs.

Having internalized key elements of the design of the Classroom Challenges, several of the pilot teachers began to use it as a template or basic structure they applied to developing their other lessons, regardless of the math topic or class. They considered whether they had a pre-assessment activity at the start of the lesson to get a sense of students' level of understanding. They weighed the amount of “teacher talk” time against small group work time. They made certain there was a debriefing portion in the lesson. They said they felt secure in the knowledge that a CC-like structure produced a strong and thought-provoking lesson with any group of students.

9. Teachers learn to expect higher levels of intellectual engagement from all of their students.

After experiencing what students could demonstrate during CCs, teachers expected a similar quality of focus and rigor in all their work with students. The Classroom Challenges served as positive proof. Seeing their students succeed with high-level, thought-demanding material, they felt comfortable, as one teacher said, “asking the students to dig a little deeper” in all classes. Teachers encouraged students to explain their thinking more fully, to ponder a problem for longer periods, and to apply their knowledge in new ways. The fact that the CCSSM also expect this kind of behavior from students bolstered teachers' determination to expect, and get, more from their students.

V. MAP Classroom Challenges Benefit Students

In addition to their own very positive experiences with the Classroom Challenges, teachers reported that using the CCs accrued a wide range of benefits to their students. The dozen teachers we interviewed spoke so explicitly and unanimously about the CCs’ influences on students that a clear picture of their positive experiences emerged, one we are able to report with a high degree of confidence.

1. Students' thinking about the *nature* of mathematics transforms.

Just as they did for teachers, the CCs helped students to reframe their thinking about the nature of mathematics—from a traditional, convention-based discipline, to one where they are required to engage as active participants, and challenged to think hard and creatively, both independently and with their classmates. Teachers reported that math became more interesting and more relevant, appealing to many more of their students, because of their interaction with the CCs.

Shifting their stance toward the subject wasn't always natural however. In the beginning, and especially among students traditionally considered "good at math," there were some who were dismissive of the CCs when they realized a formula or theorem they knew wasn't "the right answer." This wasn't math. They weren't used to performing in the new ways Classroom Challenges demand. But over time, teachers said, even the most reluctant students warmed to the CC tasks, and to a broader view of mathematics in general.

> ***We have got to help our students rethink what mathematics is, to get them to understand that it is about problem solving and thinking critically and that there is not always just one path. That is the big thing that these lessons do for me. They show students what mathematics is really about, and how rich and exciting it can be. I think for too long we have given them the impression that it is something else and that is a disservice to them. These lessons changed that perception for students.***

2. Students are more engaged in mathematics.

The Classroom Challenges raised the level of student engagement. Many of the pilot teachers were delighted to see their students deeply involved and enjoying math during the CC lessons.

> ***When I hit it just right, the kids are literally jumping with excitement, and that is not an exaggeration. They are so enthusiastic about the math that they are learning and can't wait to talk about what is going on and what they noticed. It is always challenging to find enough time for the whole class discussion because so many people have things that they want to share and things that they learned. The collaborative activity is often so rich that you don't want to stop it to have the whole class discussion, but the level of genuine excitement around the math is definitely a common theme, as are the "aha" moments, and the moments of "So that is why that happens!" That makes it so important to talk and share mathematical ideas.***

As we have mentioned, teachers recognized that the design of the CCs focuses on authentic mathematics and demands student participation and engagement. Such interactions among students generate a positive feedback cycle—engagement begets engagement.

> ***Sometimes, using our traditional lessons or books, I have felt students are just passively writing things down. I think that when using these MAP lessons they take ownership because they actually have to come up with their own thinking. It is kind of like a discovery. Students are more willing to take chances and try things, and I think they learn more because they are doing so.***

Especially encouraging for many of the pilot teachers were the reactions of students who previously had little interest in math. When working on CC tasks these students were motivated to participate in the lesson. For middle and high school teachers who have long faced the difficulty of

trying to capture the attention of students who don't fit the "good math student mold," this was a very welcome and exciting turn.

> ***We have not had our proper share of students advancing to higher mathematics in high school. We have a calculus class with only 11 kids because they have not been interested in mathematics. They haven't seen it as exciting and a chance to think critically and a challenge. However, they find these [CC] lessons exciting, and some students who I normally don't see participating are interested in the ideas and have things to say.***

3. A broad range of students have access to the mathematics while engaged in a CC.

> ***I noticed that several students who usually struggled did well during these Classroom Challenges. And several students who I thought were great students, because they were good at memorizing and mimicking, struggled during these lessons. It was eye-opening for everyone.***

Teachers said they were able to reach more students with a range of math abilities and propensities because the CCs provide multiple entry points. In the past, when operating in a more traditional instructional mode, both teachers and students often dismissed the contributions of certain classmates. In contrast, the MAP lessons offered a more open invitation, encouraging divergent, less conventional thinking from students. The typically "low end" students found alternative pathways into the CC tasks and, as a result, could contribute perspectives and skills previously unrealized in a math class.

> ***I definitely saw students who would normally not raise their hand or be afraid of giving an answer or who were unwilling to make connections change their behavior with these lessons.***

Simultaneously, at the other end of the spectrum, students who often excelled in traditional settings were challenged to clarify, articulate, and justify their thinking to others in new modes. In these ways, with greater contributions from many rather than from a few, the overall range and level of participation increased in CC classrooms.

> ***The lessons reach the whole range of students, from the lowest to the highest. The top-notch students were challenged and excited and willing to share what they learned during the lesson. Then the lower-end students blossomed. They saw things in a different light and they were able to do some of the activities. When they were doing the activity, I wasn't sure that they understood all the mathematics behind it, but at the end, the top-notch students would explain the mathematics behind it and you could see the light bulb go on for those kids.***

4. Students' mathematical understanding is enriched by the collaborative nature of CCs.

Two important and related outcomes resulted from the collaborative aspect of the MAP Classroom Challenges that occurs in various student configurations ranging from individual and independent work to whole class work. First, many students were often more comfortable offering their ideas and revealing their misunderstandings when working with peers in a small group. Those who were uncomfortable participating in larger class discussions were much more likely to engage with the math and with fellow students in a smaller setting.

The group work, whether in partners or small groups, is really critical. They learn from each other. I think some of the students who are more reluctant to participate in whole group lessons feel more comfortable when there are 2 to 4 kids in a group. They are more inclined to explain their thinking in a more comfortable setting.

The small group structure also reinforced the idea that the teacher was no longer the main source of knowledge in the classroom.

Sometimes in whole group, the concept gets lost with my presenting, and I am sure I am elevator music. In a small group, they were more apt to listen to a peer coming over. Often they just need to hear it a different way.

Students learned to rely more on each other and to take advantage of hearing a peer, as opposed to the teacher, articulate an idea or explain a problem.

While they are working at their groups, you can start seeing difficulties that individual students have, and the discussions between the kids are so valuable. A lot of times kids were teaching other kids in these lessons, whereas in my traditional classroom, I did all of the teaching. I was up front and I presented everything. Here it was amazing to listen to the kids teach each other because some of them had that knowledge and were able to pass it onto other kids.

In the collaborative groupings that the CCs demand, students expressed a variety of views and ways of thinking.

Students can see that there are lots of different ways of coming at, describing, or representing the same problem. The Challenges break down this idea that there is one way of doing something. For instance, "This is how you do multiplication." No. You can do multiplication all sorts of different ways. Then you can empower them to choose the way that makes the most sense to them.

The pilot teachers felt that being exposed to multiple perspectives expanded the thinking and learning of all students. When students heard each other's various ideas, they often made mathematical connections or unearthed misconceptions that they hadn't before—either their own or others.' Also, being exposed to multiple perspectives supported the idea (that students experienced throughout with the CCs) that math isn't always a singular, linear enterprise with only one way to solve a problem.

The most critical part for students is the collaborative piece in the center of the lesson. Everyone has access and even if they are just observing, they are watching other people make connections, which can help you make connections. Even those who are disconnected from math class, because there are those, are seeing good mathematics practice modeled for them in a group setting that they can't escape.

5. Students develop skills and attitudes that enable them to construct mathematical knowledge.

With the richer, more varied thinking and cooperation that occurred during CCs, students improved their ability to build on and deepen their individual and collective knowledge. It didn't

happen immediately, but after engaging in multiple MAP Challenges, students gradually learned to utilize what they already knew, and then to extend that knowledge with the input of others or new information—an important mathematical practice. They also learned how to argue for and defend their thinking.

> ***The whole idea of justifying something, being able to make a solid argument and backing it up, is a skill that is starting to emerge in our classroom. When I first started working with my students, I don't think they could justify anything. An answer is an answer and either it is right or it is wrong. They would always look to me—"Well who is right? Is she right or am I right?" Now I see students trying to justify their answers and trying to convince another person. I think that is a really important mathematical skill, a high level skill that my students need.***

In addition, teachers reported that their students got better at accepting some temporary confusion. "The lessons definitely teach them how to struggle more, and to sit with these non-routine problems, and to be okay when the answer isn't obvious." They learned from experience that these mistakes and missteps revealed important elements of their thinking and helped them know where to go next.

Ultimately they learned to deconstruct, revise, and rebuild their knowledge when engaged in the Classroom Challenges, and they realized that this process is what often leads to more solid and nuanced understanding.

> ***I have noticed their ability to build something and then have to break it apart and then go back to it again has improved. That can be really challenging for anybody: "I just built this and now I've got to take it apart and start over again, because something didn't work." I see them finding that less painful or less frustrating as time goes on.***

VI. In Conclusion

In concluding this report, we step far back from individual testimonials to gain a broader perspective on what we learned about MAP Classroom Challenges from the pilot teachers' experiences. There are four important ideas or findings that emerge.

First and foremost, what stands out is the non-traditional, even idiosyncratic, nature of the Classroom Challenges. We have called them "hybrids"—part investigations, part lessons, and part assessments. They are deliberately (and we think brilliantly) designed as direct, challenge-based mathematical experiences that are thought-provoking for both adolescents and adults with varying mathematical abilities. Classroom Challenges are engineered as high-demand tasks that require participants' mathematical engagement, drawing on their previous knowledge by applying what they know to new problems, and thinking hard both individually and collectively. Thus, through their involvement in these problem-oriented explorations, students and teachers alike construct new mathematical understandings.

In our view, the unique design of the Classroom Challenges is the key reason for their potency. As we have already described, almost all the pilot teachers reported that using the MAP CCs enabled them to enact what they felt the new Common Core State Standards for Mathematics called on teachers to practice in their classrooms. Their students had to engage in many of the CCSSM mathematical practices when faced with a MAP Classroom Challenge because the tasks require problem-solving, reasoning, and communication.

Of particular significance is that almost all of the pilot teachers told us that engaging with the Classroom Challenges improved their mathematics teaching overall. As we have learned over the course of more than 30 years observing classrooms, the best teachers are those who are able to build strong connections and relationships among three critical dimensions: the teacher, the student, and the subject matter. We think of this as the relationship triangle of effective instruction, and we see that the Classroom Challenges enable teachers to improve their practice by strengthening all three critical legs of this triangle. Through their use of the Classroom Challenges teachers:

- reconnect with their own love and appreciation of mathematics
- deliberately observe their students' mathematical thinking (often for the first time), gaining a new-found respect for their abilities, and
- re-conceptualize their own teaching roles and their responsibilities to their students.

Moreover, the Classroom Challenges offer teachers specific pedagogical designs and strategies for setting into motion a teaching and learning dynamic that promotes a continuing cycle of improving relationships among teacher, student, and subject matter.

Finally, we see the MAP Classroom Challenges as a rare example (one among only a handful of educational innovations we have studied over the years) of a curricular resource that achieves two important functions. The Classroom Challenges are so expertly designed that they not only realize their primary instructional purpose—to create high-quality learning experiences for students—they also indirectly serve an educative, sometimes even transformative, role for the teacher. In other words, the MAP Classroom Challenges engage students in important mathematical tasks, revealing their understanding and thinking to teachers, enabling formative assessment to occur, which is what they are intended to do. And the Classroom Challenges, when used consistently over some substantial period of time, teach teachers about mathematics and mathematics teaching. "I have changed the way I teach," was a statement from many of the teachers. Thus, the Classroom Challenges illustrate the educative and professionalizing function that exceptionally high-quality innovative materials can serve.

Inverness Research, a national education evaluation and consulting group headquartered in Northern California, has over 25 years of experience studying local, state, and national investments in the improvement of education.

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