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Supporting Implementation of the Common Core State Standards for Mathematics: Recommendations for Professional Development

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COLLEGE of EDUCATION

SUPPORTING IMPLEMENTATION OF THE COMMON CORE STATE STANDARDS FOR MATHEMATICS

RECOMMENDATIONS FOR PROFESSIONAL DEVELOPMENT

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Foreword

Who is in charge of the reality that must change to achieve the Common Core State Standards for Mathematics (CCSSM)? Teachers are. We can and should write more coherent and focused instructional materials for teachers to use, specify better uses of technology, create assessments that pull deeper instead of wider and shallower, and develop district management systems that encourage rather than inadvertently discourage spending time on good practices. But at the end of the last mile on the journey from the noble intentions of common standards to the reality of students learning, our hopes are in the hands of the teachers. This report tells us what we can do to ready those hands.

The recommendations in this report strike me as a thoughtful application of what we know about effective professional development (PD) to the problems of transitioning to mathematics teaching that achieves the CCSSM. This is a wise approach. I will comment on these from the standpoint of being one of the authors of the CCSSM, privy to the decisions, designs and trade-offs that made them what they are. I will also call upon lessons learned from decades of work in PD of teachers and principals.

First, I agree with these recommendations. But so many recommendations in education are agreeable. We are very good at saying agreeable things. A more critical question is this: are these recommendations important? For the recommendations here to be important, 'professional development' has to be important. As far as I am concerned, PD is only important if defined broadly and systemically to include the people and systems in and out of the classroom that drive teaching. These recommendations take this step; they are not just about what and how to teach teachers, they are about changing the system in which teachers work to make it a system that improves itself, and in which teachers improve their practices. Yes, these recommendations are important.

The first recommendation, "…emphasize the substance of the CCSSM….", might seem obvious, but PD practice over the last decades has not emphasized substance in mathematics. Emphasizing substance means, among other things, making time for substance. Workshop time will always be too little to be the sole, or even main source, of substance for teachers. Beyond workshops, teachers need to spend time together each week invested in the study of the substance in the CCSSM. The other elements of the system, especially where student productivity is the subject of communication among teachers, are critical: formative assessments, conversations about actual student work, classroom observations and visits and lesson study.

As the report suggests in several places, the progressions on which the CCSSM are based are a valuable asset for teacher development. Although standards are written as though a 5th grade classroom is filled with students who have learned everything in the standards from grades K-4, this is an artifice of the genre. It is not true of any classroom in this or any other country. All classrooms have a wide variety of readiness among students for today's lesson. Indeed, even within an individual child, readiness varies by the minute and by the problem. Teachers have to understand and teach to the progression that spans grades in order to deal substantively with the differences among students.

I have had the odd experience of sitting in the audience listening to someone explain something that I had written. It is surprising how often this is enlightening. On one occasion, I was stunned. When I have seen Americans present comparisons of the CCSSM to their state standards, I see cross-walks and alignments. Essentially they are comparing topics to topics by grade level, "…our state had adding fractions with unlike denominators at 5th grade, CCSSM also had at 5th grade. Bingo, no change…already aligned…". That is not what Akihiko Takahashi did when presenting to American teachers at a lesson study conference on the CCSSM.

Dr. Takahashi displayed examples of state standards for adding fractions and then the CCSSM standard for adding fractions. Then he asked, "What is different?" In other words, what do the CCSSM say about adding fractions that is different from what state standards say? Not what topics are taught in what grade level—a necessary, but superficial question—but what should we teach about this topic: a question about the substance. In this case, the CCSSM cluster heading for adding fractions standards says, "Use equivalent fractions as a strategy to add and subtract fractions". The detailed standards go on to explain how equivalence is used. This substance differs in important ways from the usual content taught for adding fractions that focuses on least common denominators and mnemonic tricks for calculation.

One last comment on substance: the CCSSM authors took great care to organize a superstructure of domains and clusters for the standards. The clusters are like sentences in a paragraph; they take part of their meaning from the paragraph they are in. Take a sentence out of its paragraph and it loses part of its meaning; it becomes vaguer, more ambiguous. In the fraction example above, the cluster heading "Use equivalent fractions as a strategy to add and subtract fractions" is the topic sentence of the paragraph. Each standard has to be read as being about equivalence as much as about fractions. Standards should not be studied and used as fragments or lists, they should be interpreted as part of a cluster. The cluster heading states the purpose of the standards in the cluster. This is part of the coherence of the standards.

In writing the CCSSM, we faced one of the biggest problems with U.S. mathematics instruction reported in international comparisons and other research, including surveys of college faculty. The problem: the American mathematics curriculum is a "mile wide and an inch deep". The CCSSM reduced the total amount of mathematics (not the number of standards) that students have to learn by taking advantage of the coherence in mathematics that lies beneath the shallow surface of answer getting. By going a bit deeper into mathematics, there is less to learn. As long as we stay on the surface of methods and procedures for getting answers, there is a vast clutter of different kinds of problems—each needing its own procedures. Under that surface are important mathematical concepts like "equivalence" that apply across many different topics and problems from fractions beginning in 3rd grade, to the everyday work of algebra changing expressions and equations, into equivalent expressions and equations. PD should pull toward this mathematical coherence and away from mere answer getting procedures and tricks. Correct answers should come from understanding and using mathematics.

Many systems for managing instruction make the mile wide-inch deep problem worse. PD must include redesigns of these systems. The most important examples are these. Every time we tell teachers their job is to cover topics, we are making the enacted curriculum a mile wider and an inch deeper. Every time we confuse covering topics faster with higher standards we are doing the opposite of high performing countries who slow down to reach higher standards. It takes time to learn; teaching should be paced to give students time to learn, not paced to cover all the topics. It is for this reason that Singapore flies the banner, "Teach less, learn more." Pacing plans make the curriculum shallower and wider. Changing the systems in which teachers work to give them feedback is as much a part of PD as workshops and coaching. Teaching is not about covering, it is about learning.

I am glad to see the emphasis on the eight Standards for Mathematical Practice in these recommendations. The authors thought of these practices as features of mathematical expertise. The CCSSM say that developing this mathematical expertise in students is a fundamental part of teaching. The development of expertise wraps around and infuses the learning of particular content and proficiencies. In many ways, these practices define the content of a person's mathematical character. Just as we develop character by modeling good character, we need to model these practices for students in the way we teach. This PD goal should come early in PD and be sustained. With the arrival widespread digital media, classroom videos exemplifying practices can make this PD more real, and more efficient.

Finally, the CCSSM redefine the goals of teaching mathematics: goals of substance and goals of practice. Once teachers understand these shifts in goals, they already have many of the competencies to achieve the goals. Many teachers also have the desire and will to acquire whatever new competencies they need to become more effective in achieving new goals. It would be as much a mistake to overestimate the PD challenge as it would be to underestimate it. We must remember the enormous contribution to PD that our partners, the teachers themselves, can and will make, given the chance, given redesigned systems that focus on learning mathematics instead of covering topics, given the time to work together and given their embrace of new goals.

The recommendations in this report can be an important guide for redesigning the systems in which teachers work, and the systems for supporting their development. Just as we need to dig in to the substance of the CCSSM to make good use of them, we need to dig in to the substance of these recommendations. Just checking our plans against the titles won't be enough. Just as when we were students, it takes a little studying to learn something new. I think this report is worth studying.

Philip Daro, Berkeley, California, 2012

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Introduction

In 2010, the National Governor's Association and the Council of Chief State School Officers published the Common Core State Standards for Mathematics (CCSSM) and to date, 44 states, the District of Columbia, and the U.S. Virgin Islands have adopted the document. These content and practice standards, which specify what students are expected to understand and be able to do in K-12 mathematics, represent a significant departure from *what* mathematics is currently taught in most classrooms and *how* it is taught. Developing teachers' capacity to enact these new standards in ways that support the intended student learning outcomes will require considerable changes in mathematics instruction in our nation's classrooms. Such changes are likely to occur only through sustained and focused professional development opportunities for those who teach mathematics.

The recommendations that follow are intended to support large-scale, system-level implementation of professional development (PD) initiatives aligned with the CCSSM. They emerged from the work done under the auspices of a NSF-funded project, which provided the opportunity for experts from diverse fields to collaboratively address the challenge of providing high-quality mathematics PD at scale to support the implementation of the CCSSM. Over the course of the project, researchers and expert practitioners worked to integrate various perspectives on this challenge into a set of design recommendations for creating, sustaining, and assessing PD systems for practicing mathematics teachers. Generated from the coordination of research-based knowledge in different but related fields, these recommendations build on state-of-the-art research findings from mathematics education, PD, organizational theory, and policy.

The recommendations take into account the important role teachers will play in making the standards a reality. A substantive body of research points to teachers as the most important factor in promoting mathematics learning, and the education of teachers has been deemed an essential aspect in promoting educational improvement. Thus, the recommendations proposed here make salient that attending to the PD of practicing mathematics teachers in light of the CCSSM is a requirement for the successful implementation of the new standards.

It is important to note that these recommendations are intended to build on, rather than replicate, the features of effective PD identified in prior research (e.g., Desimone, 2009; Elmore, 2002; Guskey & Yoon, 2009; Guskey, 2000). In particular, a recent report from the National Staff Development Council (Darling-Hammond et al., 2009) entitled, *"Professional Learning in the Learning Profession: A Status Report on Teacher Development in the United States and Abroad"* identified four basic, research-based principles for designing PD that we understand as common professional and research knowledge that serves as the foundation on which the current recommendations are built: 1) PD should be intensive, ongoing, and connected to practice; 2) PD should focus on student learning and address the teaching of specific content; 3) PD should align with school improvement priorities and goals; and 4) PD should build strong working relationships among teachers. We hope that the recommendations that follow, in conjunction with these four basic principles, can help districts and states in creating, sustaining, and assessing PD systems for practicing mathematics teachers that support their implementation of the CCSSM, and ultimately, the learning of all K-12 students.

NOTE: The abbreviation CCSSM-PD is used through the recommendations in order to avoid consistently reminding the reader that the recommendation is specifically about professional development that supports enactment of the Common Core State Standards for Mathematics.

Overview of Recommendations

1: Emphasize the Substance of CCSSM-PD

Professional development provides opportunities for practicing mathematics teachers to engage with both the CCSSM content and the CCSSM practices in a focused and integrated way.

2: Create and Adapt Materials for Use in CCSSM-PD

Professional Development materials are needed that explicitly address the mathematics content and practices of the CCSSM and provide vivid images of teaching and learning that are consistent with CCSSM.

3: Design CCSSM-PD Based on Features that Support Teacher Learning

Professional development takes into account existing knowledge about effective ways to organize learning experiences for teachers of mathematics.

4: Build Coherent Programs of CCSSM-PD

Programs of professional development provide a continuous and coherent set of experiences in which practicing mathematics teachers engage over an extended period of time.

5: Prepare and Use Knowledgeable Facilitators for CCSSM-PD

Professional development uses expert facilitation to ensure teacher learning of CCSSM at scale.

6: Provide CCSSM-PD Tailored to Key Role Groups, in Addition to Teachers

Strong programs of professional development target a variety of role groups within the education system and attend to the professional needs of each group as the system builds capacity at all levels.

7: Educate Stakeholders about the CCSSM

Members of the general public need to be apprised on how the CCSSM will impact instruction and learning in our nation's classrooms.

8: Continuously Assess CCSSM-PD

Professional development programs are regularly assessed to provide formative information for program improvement and revision and to establish the effectiveness of the programs.

9: Create CCSSM-PD Consortia

Professional development consortia are needed to oversee and improve the role professional development plays in successful implementation of the CCSSM.

RECOMMENDATION # 1 EMPHASIZE THE SUBSTANCE OF CCSSM-PD

Professional development provides opportunities for practicing mathematics teachers to engage with both the CCSSM content and the CCSSM practices in a focused and integrated way.

Elaboration:

The substance (Kennedy, 1998) or content focus (Desimone, 2009; Garet et al., 2001) of any professional development (PD) is a key component for providing teachers with opportunities to learn. PD designed to support the CCSSM emphasizes the mathematics content and the mathematics-specific practices identified in the standards. Such PD targets a defined and focused set of mathematical content and practices. It makes salient how students develop mathematical ideas over time (i.e., standards progressions) and the ways in which the mathematical practices support the learning of content.

The mathematical ideas selected for initial focus in PD are those that are treated differently in CCSSM than in previous standards (e.g., transformational geometry), ones that may be new to teachers at a particular grade level (e.g., earlier attention to unit fractions, data and statistics in middle grades, ratios and proportional relationships in grade 6) or are foundational to what is to come in later grades (operations and algebraic thinking k-5). A recent report entitled, *Gearing up for the Common Core State Standards in Mathematics* (2011) identifies five initial content domains for PD in grades k-8 to be used as a starting point for such work. They are: (1) counting and cardinality and number and operations in base ten (grades k-2); (2) operations and algebraic thinking (grades k-5); (3) number and operations-fractions (grades 3-5); (4) ratios and proportions (grade 6-7); and (5) geometry (grade 8).

The mathematical practices presented in the CCSSM represent important habits of mind that teachers must learn to incorporate and promote in the classroom. Just like the content standards, PD targets a few selected practices to address in depth. These practices must be embedded in discussions about content. The standards for mathematical practice are an especially critical part of PD that supports the CCSSM because the practices define what mathematics teaching and learning should look like. Teachers need opportunities to experience specific practices as learners before they can be expected to enact them as teachers. For example, teachers need opportunities to construct viable arguments themselves so that they understand what this practice means and are in a better position to consider what this practice looks like in their own classroom.

Suggested Action Steps:

- **School Leaders:** Make teachers' experiences with CCSSM content and practices a priority, allocating time and resources for teachers to discuss and reflect on the CCSSM standards progressions, new practices, and the ways in which content and practices support each other in instruction.

- **District or State-Level Personnel:** Organize and offer PD that is focused on a few specific content standards progressions and integrates mathematical content and practices. Over time, a broad set of content and practices can be addressed, but this should be done sequentially rather than all at once.

- **Professional Development Providers:** Design PD that addresses specific content strands and integrates the CCSSM content and practices.

RECOMMENDATION # 2: CREATE AND ADAPT PROFESSIONAL DEVELOPMENT MATERIALS FOR USE IN CCSSM-PD

Professional development materials are needed that explicitly address the mathematics content and practices of the CCSSM and provide vivid images of teaching and learning that are consistent with CCSSM.

Elaboration:

Professional development (PD) materials that support the CCSSM target specific content and/or practices and provide opportunities for teacher learning that are grounded in practice; that is, the everyday work of teaching is the object of ongoing investigation and thoughtful inquiry (Ball & Cohen, 1999; Smith, 2001). Such materials include: assessment items, video and narrative exemplars of students using the mathematical practices in pursuit of learning key content, sets of related tasks that promote learning of specific mathematical ideas and show a trajectory of how knowledge builds over time, and samples of student solutions to specific tasks, as well as students' misconceptions, highlighting the range of strategies that students might use to solve a particular task.

Practice-based PD materials provide opportunities for teachers to enhance their understanding of both CCSSM content and practices. Teachers develop new levels of awareness and knowledge through engagement with these PD materials and learn to examine their current instructional practices and curricular materials in light of the new ideas represented by the CCSSM.

Suggested Action Steps:

- **District or State-Level Personnel:** Collect artifacts from teachers (e.g., tasks, lesson plans) and classrooms (e.g., video, student work samples) that highlight aspects of the CCSSM that can be used locally in connecting PD with teachers' practices.
- **Authors of Professional Development Materials:** Create indices that identify the ways in which the mathematical content and practices from CCSSM are made salient in existing materials.
- **Funding Agencies and Publishers of Professional Development Materials:** Allocate funds for the development of new, or the adaptation of existing, materials for use in PD settings that promote the CCSSM.
- **Funding Agencies:** Allocate funds for research on the enactment and effectiveness of these PD materials in support of the CCSSM within various settings.

RECOMMENDATION # 3: DESIGN CCSSM-PD BASED ON FEATURES THAT SUPPORT TEACHER LEARNING

Professional development takes into account existing knowledge about effective ways to organize learning experiences for teachers of mathematics.

Elaboration:

Substantial evidence has been amassed about features of professional development (PD) that make certain initiatives more effective (e.g., Darling-Hammond et al., 2009; Garet et al., 2001; Guskey & Yoon, 2009). These features include: PD should be intensive, ongoing, and connected to practice; PD should focus on student learning and address the teaching of specific content; PD should align with school improvement priorities and goals; and PD should build strong working relationships among teachers. Whereas two of these features were highlighted in recommendations #1 and #2 due to their importance (emphasis on substance of PD and connections to teaching practices), the design of PD that supports the CCSSM takes into account all other features that relate to the ways in which PD promotes teacher learning, such as: offering a substantial number of PD hours; spreading these hours over time; aligning the PD goals with school improvement priorities; attending to student learning; and fostering strong working relationships among teachers.

Features of effective PD do not prescribe the means through which PD is delivered. Using a variety of delivery mechanisms to make PD available to teachers assures that such initiatives fit a myriad of teacher schedules and working conditions. Combinations of summer and year-round work, face-to-face and virtual meetings, job-embedded and course-based activities, within-school and outside-of-school experiences, allow PD to be compatible with teachers' time and availability.

Recent research indicates that although necessary, these features alone many not be sufficient to impact instruction (Garet et al., 2010; Garet et al., 2011), suggesting that PD in support of the CCSSM also incorporates practices the field has begun to see as promising, such as attention to discourse (Chapin, O'Connor, & Anderson, 2009; Smith & Stein, 2011), development of high-leverage practices (Grossman et al., 2009; Lampert et al., 2010), student thinking (Carpenter et al., 1989), formative assessment (Wiliam & Thompson, 2007), and cognitively challenging mathematical tasks (Smith & Stein, 1998). These PD opportunities offer teachers feedback on their own knowledge, instruction, and their students' progress.

Suggested Action Steps:

- **Teachers:** Examine whether the PD experiences you choose in support of CCSSM attend to important features of effective PD. Let school leaders know of PD that does not adhere to these features and does not provide you with opportunities to learn about the mathematics content and practices of CCSSM.

- **School leaders:** Select only PD options that are in line with known features that support teacher mathematics learning.

- **District and State-Level Personnel:** Allocate funds only to PD opportunities that incorporate known features that support teacher learning.

- **Publishers of Professional Development Materials:** Make available PD materials in support of the CCSSSM that take into account key features of effective PD and include facilitators' manuals with suggestions on how to organize the PD accordingly.

- **Funding Agencies:** Allocate funds for research on what makes PD effective so that the field can strengthen and use knowledge about what is required in PD. Require that the design and implementation of the PD you fund in support of CCSSM make clear use of known features that support teacher learning and are focused on mathematics.

RECOMMENDATION # 4: BUILD COHERENT PROGRAMS OF CCSSM-PD

Programs of professional development provide a continuous and coherent set of experiences in which practicing mathematics teachers engage over an extended period of time.

Elaboration:

Programs of professional development (PD) provide opportunities for teachers to engage with CCSSM content standards progression and practices over an extended period of time. Such programs warrant that the collection of PD experiences in which teachers engage provide an overall consistent message about what the CCSSM is and how it should be incorporated into instruction to improve mathematics teaching and learning. In addition to ensuring that each PD initiative emphasizes substance, uses materials that are tightly connected to teaching practices, and incorporates features that support teacher learning, a program of PD takes into account teachers' experiences across all initiatives, making sure the set of experiences is coherent.

A current problem with PD is that available opportunities are frequently fragmented and episodic, including both high- and low-quality work, strong and weak learning opportunities, generic and content-focused activities, appropriately and poorly focused learning experiences, in part because PD is supported and coordinated through many different types of organizations. Offering isolated PD opportunities that are not articulated into a coherent program ignores the need for teachers' experiences in PD to logically build on one another so that teachers can accumulate knowledge over time (Cobb & Smith, 2008). A purposeful articulation across many PD initiatives makes sure that available options are not only high quality and focused, but also appropriately sequenced and connected to create meaningful long-term PD paths in support of CCSSM.

Suggested Action Steps:

- **School Leaders:** Clarify and communicate school improvement priorities in relation to the CCSSM so that programs of PD can be designed to align with such priorities.

- **Professional Development Providers:** Offer sets of extended PD opportunities that support the development of teacher knowledge base for teaching a particular slice of mathematics over time.

- **District or State-Level Personnel:** Select PD opportunities for teachers that are focused and sustained over a period of time, and that build on one another in coherent ways. Do not fund on-off PD that is not tied to the goals established for your PD program.

- **Professional Organizations:** Disseminate information regarding the need for teachers to engage in programs of PD opportunities that are aligned with CCSSM and are combined in coherent ways to support teacher knowledge growth over long period of time.

RECOMMENDATION # 5: PREPARE AND USE KNOWLEDGEABLE FACILITATORS FOR CCSSM-PD

Professional development uses expert facilitation to ensure teacher learning of CCSSM at scale.

Elaboration:

Successful facilitation of professional development (PD) requires expertise (Banilower, Boyd, Pasley, & Weiss, 2006; Elliott et al., 2009), and PD participants are far more likely to achieve the targeted learning goals when skilled and knowledgeable providers facilitate the PD. Expert facilitators for PD that support the CCSSM are at a minimum well-versed on the CCSSM content standards progression and practices, as well as on how to build learning environments that take into account teachers' needs and are supportive of teacher learning as highlighted in previous recommendations. Further, expert facilitators are knowledgeable about leadership, adult learning, successful innovations, and are up-to-date on research results about best practices in mathematics education. Expert facilitation can come from within the system or from outside the system, but requires an understanding of the ambient PD (Wayne et al., 2008) that is in place.

The capacity problem for developing expertise in PD facilitation is large (Cohen & Ball, 1999; Sztajn, Ball, & McMahon, 2006) and one that needs to be addressed to support the implementation of CCSSM at scale. Working to develop facilitation capacity requires the identification and adequate preparation of a whole new cadre of professionals within the educational systems who can lead successful PD for all teachers.

Suggested Action Steps:

- **District or State-Level Personnel:** Consider the expertise in mathematics teaching and learning of the PD providers and facilitators, both from within and from outside the system. Support the development of a cadre of mathematics professional development leaders within the educational system.

- **Professional Development Providers:** Identify the knowledge and expertise used in facilitating PD that supports the CCSSM and make such knowledge available to provide for the preparation of a new cadre of mathematics PD providers.

- **Publishers of Professional Development Materials:** Include in PD materials information that purposefully targets the needs of new PD facilitators.

- **Funding Agencies:** Allocate funds for research on features of effective PD facilitation and how to prepare mathematics PD facilitators at scale to address the capacity problem.

RECOMMENDATION # 6: PROVIDE CCSSM-PD TAILORED TO KEY ROLE GROUPS, IN ADDITION TO TEACHERS

Strong programs of professional development target a variety of role groups within the education and system attending to the professional needs of each group as the system builds capacity at all levels.

Elaboration:

Because the CCSSM represents changes in both what mathematics is taught and how it is taught, professional development (PD) needs to build capacity at various levels within the educational system. Offering PD in support of the CCSSM that includes various key role groups in the system (e.g., department chairs, instructional leaders, school administrators, superintendents) ensures that all professionals in the system understand the new content and practices in the CCSSM and share a vision for mathematics instruction in the system. PD experiences conducted with a diverse group of professionals fosters coherence and aligns expectations within the system for supporting teaching and learning in light of the CCSSM.

Different professionals in the system also have different needs, and role-specific PD opportunities target the demands of specific groups. Such targeted PD for professionals other than teachers assures that those functioning in different capacities within the system are properly prepared to support the implementation of CCSSM. For example, PD for principals helps them know what content teachers need to be teaching and what to look for when they observe classrooms (Nelson, 1998; Spillane, 2005). PD for superintendents helps them understand the need for coherence across the system in supporting teacher learning of the CCSSM (Cobb & Smith, 2008). When the goals and content of PD across all targeted role groups are aligned with what each group needs to support the CCSSM, the system can support teachers in changing instructional practices, as well as hold them accountable for doing so.

Suggested Action Steps:

- **District or State-Level Personnel:** Consider the PD needs of various key role groups and provide targeted mathematics PD to all groups in support of the CCSSM.

- **Funding Agencies and Publishers of Professional Development Materials:** Allocate funds for the development of different PD materials that target the needs of various school professionals such as instructional leaders, principals, and other administrators. These materials should inform all professionals about the CCSSM and consider role-specific needs related to the CCSSM implementation,

RECOMMENDATION # 7: EDUCATE STAKEHOLDERS ABOUT THE CCSSM

Members of the general public need to be apprised on how the CCSSM will impact instruction and learning in our nation's classrooms.

Elaboration:

Mathematics teaching will be transformed as the CCSSM is implemented. Those who understand how teaching will look different as the CCSSM becomes a reality in our nation's classrooms need to educate parents, politicians, school boards, businesses partners, industry representatives, and other interested parties about what to expect from mathematics teaching that supports the implementation of CCSSM. It is also important to inform stakeholders of the reasons why new content standards progressions and practices are proposed in the CCSSM and why teaching approaches being used in classrooms are likely to be more effective in supporting student learning.

In particular, parents need to understand what their children are working on in school and be positioned to better support children's learning (Civil & Bernier, 2006). Educating stakeholders outside the educational system such as politicians, business partners, or industry representatives makes sure they are informed of expected changes and can advocate for the CCSSM with their own constituents.

Suggested Action Steps:

- **District of State-Level Personnel:** Work with others to educate state policymakers and legislators about the CCSSM and the policy and fiscal needs for professional development for teachers at all levels.

- **Professional Organizations:** Take the lead in developing ways to communicate to parents, policy makers, school board members, and other stakeholders to advocate for research-based teaching mathematics practices that support the CCSSM and explain why these practices are more likely to lead to improved student learning outcomes.

- **Funding Agencies:** Allocate funds for researchers and developers to communicate the results of their work to public audiences and to include experts on communication and dissemination in efforts to launch information campaigns.

RECOMMENDATION # 8: CONTINUOUSLY ASSESS CCSSM-PD

Professional development programs are regularly assessed to provide formative information for program improvement and revision, and to establish the effectiveness of the programs.

Elaboration:

Professional developers incorporate assessment and evaluation practices into their work so that regular, cyclic patterns of feedback shape the refinement of professional development (PD) materials and programs. Consistent with the current emphasis on evidence-based practices and programs, mathematics PD needs to provide evidence of effectiveness and the use of data-driven decision making. Assessments of PD are tied to specific PD goals and evaluation includes a formative component, providing feedback for improving professional development and targeting support to teachers in order to improve their knowledge, practice, and student learning.

Similar to design experiment cycles that have informed mathematics curriculum development and improvement (e.g., Cobb, Confrey & diSessa, 2003), formative assessment cycles support the improvement of PD. Formative assessment focuses on PD curriculum, the impact of PD on teacher practice, the impact on teacher beliefs, and facilitator development.

Suggested Action Steps:

- **School Leaders:** Use interim assessments tied to CCSSM to inform teachers about what is working for them instructionally and inform PD providers about needed adaptations.

- **District or State-Level Personnel:** Select PD programs that have specific and clear goals and objectives; be aware of the variety of assessment instruments that measure how the goals and objectives are met and the limitations of each instrument; use the evidence you gather about participation in PD to locally improve your programs of PD for practicing mathematics teachers.

- **Assessment Developers:** Develop instruments that provide both formative and summative assessment information on what teachers and other key role groups learn from their participation in PD related to the CCSSM. Identify observable changes in teacher classroom practice such as coherence with respect to standards progressions or integration of mathematical practices, and develop instruments to analyze classroom practice in light of the CCSSM.

- **Funding Agencies and Publishers of Professional Development Materials:** Allocate funds for the development of measures and instruments for assessing what teachers learn and use from their participation in PD related to the CCSSM.

RECOMMENDATION # 9: CREATE CCSSM-PD CONSORTIA

Professional development consortia are needed to oversee and improve the role professional development plays in successful implementation of the CCSSM.

Elaboration:

In parallel with the creation of the assessment consortia (SMARTER Balanced Assessment Consortium and Partnership for Assessment of Readiness of College and Careers), through the competitive Race to the Top Assessment funding competition, there is now a need to create similar professional development (PD) consortia. They set the stage for the next generation PD in mathematics, coordinated by consortia of states. The PD consortia could also serve as clearinghouses for mathematics PD materials, programs, and providers in order to support states and districts in making decisions about mathematics PD in support of the CCSSM. The creation of PD consortia addresses the current lack of certification for PD providers and these consortia can work with professional organizations to develop models of instruction that is aligned with the CCSSM. The PD consortia can help facilitate the sharing of information between assessment developers and PD providers, contributing to a streamlined system of mathematics education.

The initial scope of work for these PD consortia includes, but is not limited to: (1) overseeing the creation of a clearinghouse (or clearinghouses) for PD materials that are aligned with the CCSSM, are of high quality, and can be used in the PD of mathematics classroom teachers, instructional-leaders, school administrators, and other key role groups; (2) setting quality standards for mathematics PD materials in support of the CCSSM; (3) providing recommendations for the development of state- and district-wide mathematics PD programs and exemplars of such programs; (4) developing a certification system for well-prepared mathematics PD providers and develop a pipeline of such providers; (5) supporting and expanding research around the role of PD related to the CCSSM, including not only the continuation of efficacy trials around PD offered by the developers on small scale, but also effectiveness studies that generate new knowledge about providing PD at scale; and (6) documenting the effects of the PD changes to the PD system.

Suggested Action Steps:

- **Funding Agencies:** Develop competitions to fund CCSSM Professional Development Consortia.

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The goal of this project was to initiate and support collaborative work among experts from different fields of research in generating a set of documents that addressed the nation-wide problem of needing to provide high quality mathematics professional development (PD) at scale to support the implementation of the Common Core State Standards for Mathematics (CCSSM). Over the course of the year, researchers worked through a set of activities designed to integrate various perspectives on this problem into a set of design recommendations for what should be considered when creating, sustaining, and assessing PD systems.

1. Preparation of Briefs:

The project started with the identification of a diverse set of expert researchers in the areas of mathematics, PD, equity, assessment, policy, and system research, as well as "high leverage" practitioners who were informed consumers of and participants in research related to the mathematics education of teachers. These experts were selected because of the contributions their specific knowledge within their fields could make to mathematics teacher education.

All invited participants were asked to submit a two page brief in which they:

- described, based on their expertise and knowledge of research, what it would take to design, implement, or assess the quality of mathematics PD that would support the implementation of the CCSSM content and practices;
- described, in some detail, one idea they had for how PD could be done at scale (i.e., with a whole district or an entire state) to support the implementation of the CCSSM; and
- identified a small number of articles that influenced their thinking.

Participants were asked to write their briefs bringing their own areas of expertise, knowledge of research, and points of view to bear on the questions. All written briefs are included in this report. Participants were also informed that the collection of briefs generated through this process would provide the basis for the ideas to be discussed and synthesized over a two-day, face-to-face meeting of all experts. Representatives from five national professional organizations whose missions address aspects of mathematics teachers' PD (Association of Mathematics Teacher Educators (AMTE), Association of State Supervisors of Mathematics (ASSM), Mathematics Association of America (MAA), National Council of Supervisors of Mathematics (NCSM), and National Council of Teachers of Mathematics (NCSTM)) also participated in the two-day, face-to-face meeting.

Prior to the face-to-face meeting, all meeting participants were assigned to mixed-expertise small groups and received all the two-page briefs written by members of their small groups. They were asked to carefully read the set of briefs they received prior to the meeting and identify common recommendations for PD as well as conflicting points of view. Participants were expected to come to the meeting prepared to engage in conversations among researchers and practitioners with diverse perspectives.

2. Meeting of Research-Experts

The meeting occurred on May 12-13 at the Friday Institute for Educational Innovation, North Carolina State University, Raleigh, NC. It brought together approximately 40 research experts, as well as representatives from participating professional organizations (AMTE, ASSM, MAA, NCSM, NCTM), the U.S. Department of Education, and the North Carolina Department of Public Instruction. A list of all participants follows. The event was designed to allow for considerable interaction between participants.

On the first day, after welcoming remarks by North Carolina State University Chancellor Dr. Randy Woodson, Friday Institute Executive Director Dr. Glenn Kleinman, and Project Principal Investigator Dr. Paola Sztajn, the experts were divided into mixed-expertise small groups to brainstorm, elaborate, prioritize and finalize recommendations for what should be considered when creating, sustaining, and assessing PD systems at scale and in line with the CCSSM. Participants were asked to consider the extent to which their recommendations were applicable to working at scale and the extent to which their recommendations specifically supported the CCSSM. Each group created a poster that contained the group's final list of recommendations, prioritized and numbered, which were shared with all the groups in a gallery walk. Each group had ten minutes to review the list of recommendations prepared by the other groups and to indicate whether they were similar to recommendations that appeared on their own group's list or they did not appear on their own group's list but should be on the final list of recommendations.

To conclude events of the first day, three guests provided commentary. First, Dr. Michael Lach, Special Assistant in Science, Mathematics, Engineering, and Technology Education at the U. S. Department of Education, shared his observations of the meeting's work and discussed the challenges of implementing the CCSSM. Next, Dr. Dan Heck, Senior Research Associate at Horizon Research, spoke about challenges for PD and the scale of implementing PD to support the CCSSM. Finally, Dean of the North Carolina State University College of Education Dr. Jayne Fleener welcomed the group to the university and discussed her observations about the group's work, and encouraged the group to "Think Locally, Act Globally" about the problems of implementing systems of PD. The floor was then opened to participating experts and other meeting observers to share their thoughts, comments, and questions in a public forum.

On the second day, the meeting began with the Principal Investigators offering a synthesis of emerging issues from the previous day, addressing issues such as the content of, materials for, quality of, and pre-existing necessary conditions for quality PD for practicing mathematics teachers. The Principal Investigators called attention to recommendations that were good recommendations for PD in general, but perhaps not attentive enough to the current moment, and recommendations that addressed the conditions under which PD is offered, but perhaps not the PD itself. The project Principal Investigators challenged the group to think about how recommendations made the previous day could be more specific to the new issues raised by the CCSSM, and the challenge of implementing the CCSSM-focused PD programs.

Unlike the groupings on Day 1, which, by design, brought participants with different perspectives together, the intent of Day 2 was to give participants with similar expertise an opportunity to review the emerging recommendations from their professional perspectives. Therefore, participants were grouped by areas of expertise and asked to: consider the audience they wanted to reach; select three recommendations that were top priorities from their perspective; and examine how the recommendations would be useful to their target audience. Recommendations that emerged from these similar-expertise groups were then shared and discussed with the entire group.

A panel presentation by the representatives from the participating professional associations followed. Each representative shared the perspectives about and current activities related to PD and the CCSSM as they related to each organization's constituents. The meeting concluded with a final discussion and Q&A session.

3. Follow-up Work

After the meeting, graduate students who had been assigned to small groups during both meeting days prepared a summary of the major discussion points from their groups, as well as a list of issues discussed in the groups, but not included in the final list of recommendations. They also compiled the recommendations that were listed in each of the group posters from the first day, indicating the extent to which each group viewed the recommendations as important. Recommendations from the second day were also compiled in a list.

Drawing on these materials, the project Principal Investigators analyzed the recommendations and organized them into categories, first individually and then collectively, looking for emerging common themes and categories among the work of the various groups. After a cycle of creation and refinement, the Principal Investigators crafted a set of initial recommendations that included a research-based elaboration and a set of specific action steps for different actors in the educational system.

4. Member Check and Feedback

The initial recommendations were sent to all project participants, who were encouraged to send feedback and suggestions to the Principal Investigators. In addition, four participants with different areas of expertise were invited to provide a more detailed review of the recommendations, answering a set of specific questions. The final set of nine recommendations resulted from the analysis of the feedback and detailed commentary. This set was then sent to the partner professional associations for their final comments and was reviewed one more time to address potential issues raised by representatives from the professional associations.

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What Would it Take to Design and Implement System-level Professional Development?

As noted in the information provided to participants, our work as a group begins with four research-based principles for designing professional development (PD), that PD should: 1) be intensive, ongoing, and connected to practice; 2) address student learning in a specific content area; 3) align with school improvement priorities; and 4) build strong working relationships among teachers. I propose adding two principles, also supported by research, to this list: 5) PD should model preferred instructional practices and actively involve teachers in their learning; 6) PD should be sustainable and scalable (Borko, Jacobs & Koellner, 2010; Desimone, 2009). Our focus on the CCSSM content and practices further specifies the substantive focus of the PD.

For a PD model to be scalable, its design features and core principles must be well specified so that PD leaders other than the original developers can enact it in a wide range of local contexts, while maintaining integrity to its core principles. To be sustainable, the model must build local capacity and adjust to local contexts so that the work can be carried out by schools and districts on a long-term basis, using internal resources, without support by the original designers. Thus, another central feature of a sustainable, scalable model is the ability to prepare PD leaders who can adapt the model to their local contexts while maintaining integrity to its core principles. These leaders must be able to engage teachers in productive mathematical work, lead discussions about student reasoning and instructional practices, and build a professional community (Borko, Koellner & Jacobs, 2011).

An Idea for Conducting Mathematics Professional Development at Scale

The specific ideas that I offer in this brief are based on my design research in Colorado with colleagues Jennifer Jacobs and Karen Koellner to develop a sustainable, district-level mathematics professional development model (Koellner, et al., 2008). The ideas build on the program we developed, incorporating modifications based on our experiences in Colorado. The program has two components: a PD model (the Problem-Solving Cycle) and a PD leader preparation model (Mathematics Leadership Preparation).

Problem-Solving Cycle (PSC). The PSC is an iterative, long-term approach to mathematics PD designed to increase teachers' mathematics knowledge for teaching, improve their instructional practices, and foster student achievement gains. Each "cycle" is a series of interconnected workshops organized around a rich mathematical task. In the first workshop(s), teachers explore the mathematics entailed in the problem and plan a lesson adapting the problem to their students. They then teach the lesson to provide a common teaching experience. Subsequent workshops use video and other artifacts as a springboard for discussing strategies for teaching with problems such as eliciting and supporting students' mathematical thinking, analyzing student work to inform ongoing instruction, and developing the academic language of mathematics.

Because the PSC is designed as an adaptive model of PD, leaders construct specific goals for each workshop to meet the needs of participating teachers. Key features that are generalizable to other PD models include fostering a professional learning community, engaging teachers in solving and analyzing mathematical tasks, and using artifacts from the teachers' own classrooms as a context for their learning. Adaptations of the PSC to address the CCSSM could include highlighting specific content standards as teachers solve and analyze the math tasks, and selecting video clips that can be used to foster discussions of students' engagement in the CCSSM practices.

Mathematics Leadership Preparation (MLP). The MLP is a refinement of the leadership preparation model originally developed by the Colorado research team. Although designed to prepare school-based PD leaders for the Problem Solving Cycle (PSC), its features are applicable more generally to PD leader preparation. The model has three major components: introduction to the PSC, a summer leadership academy, and multiple cycles of structured guidance for facilitating the PSC.

As a first step in the MLP, math leaders—typically one or two per school—participate in one cycle of the PSC facilitated by experienced PSC PD leaders. As participants, they gain first-hand experience of how the model works, observe how it is facilitated, and reflect on their own learning. In the second component, MLs participate in a summer leadership academy, conducted by experienced PSC PD leaders, during which they transition from their role as PD participants to PD leaders. They participate in multiple PSC simulations and develop plans for implementing the PD with the mathematics teachers in their schools. In initial simulations, the experienced leaders model practices central to successful enactment of PSC workshops. Subsequently MLs plan and then take turns leading the various activities that comprise the workshops. These simulations represent what Grossman and McDonald (2008) refer to as "approximations of practice" – "opportunities to rehearse and develop discrete components of complex practice in settings of reduced complexity". In the third component, experienced leaders provide on-going structured guidance as MLs facilitate multiple iterations of the PSC with the math teachers in their schools. For each cycle, MLs attend three "preparation meetings" led by experienced leaders: one prior to conducting the workshops to solve the problem and plan the lesson, one after teachers' lessons with the problem, and one after at least one workshop analyzing clips from video of the teachers' lessons. These meetings assist MLs in planning and conducting all aspects of the PSC workshops, including orchestrating mathematical discussions, selecting video clips, writing guiding questions, and leading discussions based on the video clips. They also address ways to tailor the workshops to each ML's school context. In addition, experienced leaders are available to MLs on an as-needed basis throughout the school year to address concerns that may arise outside of the preparation meetings.

Next steps. The sets of PD practices and leadership preparation practices identified in this brief provide an initial model. There is more work to be done to identify additional practices, characterize the specific activities that comprise those practices, and determine the knowledge required for their successful enactment.

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Idea for Design and Implementation

In order provide professional development (PD) that is intensive, ongoing, and connected to practice, a statewide PD plan would need to use a multi-faceted approach to effectively reach teachers, paraprofessionals, administrators, and state leaders. The approach described addresses key features characteristic of a well-designed PD program, as identified by researchers and national organizations, including: (a) a supportive context with strong leadership, (b) strong content, grounded in research, that includes mathematics content and practices, and (c) an effective process of implementation.

First, the state plan involves key leaders across a state in professional development (e.g., Leadership Institutes) for the purpose of educating leaders about CCSSM and building capacity and support for the initiative in each state. Second, the state plan requires targeted personnel from participating schools to attend annual intensive Summer Mathematics Academies. These academies would serve the purpose of focusing in greater detail on the CCSSM content and practices. Third, the state plan requires LEAs to engage in follow-up support opportunities, including grade-level team meetings, staff development workshops and courses, mentoring and coaching, observations and demonstration lessons, and technical support, including regular communications with the state department to monitor program progress. Developing a professional learning community within each LEA is essential for successful implementation of the CCSSM. Fourth, the state plan requires the state to provide outreach workshops to non-participating schools in order to reach additional pockets of at-risk populations. All of these expectations intend to provide sufficient time and resources to develop capacity and expertise at the state and local level.

Description of State Professional Development Activities

Professional Development Providers/Coaches Support Network: The purpose of the PDP/C Support Network is to ensure that those who are responsible for delivering the PD activities have regular opportunities to (a) ensure a common understanding of CCSSM content and practices, (b) plan for various PD activities in consultation with the state coordinator and in response to ongoing needs assessment data collected from participating schools (c) consult with each other as well as role-alikes from other states regarding implementation of PD program, (d) further investigate relevant research by participating in the Research Study Group, and (e) attend various leadership and professional meetings in the state that may have an impact on the CCSSM initiative. Criteria for selection of PDP/C members would include (a) mathematics education background, (b) extensive experience with adult learning contexts, (c) experience working in PK-12 classrooms, (d) strong leadership, organizational, and communication skills, and (e) deep understanding of CCSSM. The PDP/C members provide a monthly report to the state Coordinator and play a key role in providing technical assistance to local schools by working closely with the LEA *site coordinators* who are responsible for carrying out the logistical implications of the CCSSM initiative.

Research Study Group: The purpose of the Research Study Group is to inform stakeholders of key research findings that have relevance to the implementation of the CCSSM. The group, which will represent educational leaders from around the state, would meet quarterly to discuss research—recent and past studies—further informing their understanding of CCSSM. The group will be responsible for reporting their findings to the state's Coordinator so that this information may be disseminated among participating school sites and used for PD activities.

Leadership Institute: The purpose of the Leadership Institutes is threefold: (a) to inform educational leaders (representatives from higher ed, legislators, BOE, DOE, superintendents, principals, and professional mathematics organizations) about the ongoing implementation of the CCSSM initiative at the state and local level, (b) to enlist the insights of educational leaders regarding the implementation of CCSSM, and (c) to identify specific action plans at the leadership level that can further support the CCSSM initiative in the state. The Leadership Institute will be held once a year in the spring, with regular communications provided throughout the year.

Math Academy Trainers Workshop: The purpose of the Math Academy Trainers Workshop is to provide training for those trainers who will assist in presenting at the Summer Math Academies. In densely populated states, PDP/C members are responsible for providing the training for Math Academy Trainers. In less populated states, this activity may be determined unnecessary with PDP/C members leading the Summer Math Academies.

Summer Math Academies: The purpose of the Summer Math Academies is to provide an intensive, one-week PD experience to participating *school teams*. The teams will consist of all educators in the school who are responsible for math instruction, including classroom teachers, special service providers, paraprofessionals, tutors, and administrators.

On-Site Visits and Training: The purpose of the On-Site Visits and Training is for the PDP/C members to provide ongoing support to participating schools. Specifically, On-Site Visits will take place on a weekly or bi-weekly basis and will include the following components: (a) technical assistance and coaching for *site coordinator*, (b) demonstration lessons, (c) written and video-taped observations of teachers, (d) data collection and analysis to guide ongoing PD, (e) coordination of additional PD opportunities, and (f) meetings with administrators and/or board members.

Site Coordinator Training: Each participating school would be expected to hire an on-site coordinator. This person's responsibilities include: (a) overseeing the implementation of the CCSSM, (b) meeting with the teacher teams as a group and individually to identify needs, (c) observing team members to ensure implementation fidelity of CCSSM, (d) building expertise and capacity within the school, and (e) working with the PDP/C member in preparation for on-site visits and to receive technical assistance. This person serves as the key liaison between the DOE, the PDP/C member, and the school's teacher teams, including administrators and board members.

State Outreach Workshops: The purpose of the State Outreach Workshops is to provide PD to non-participating schools. Of particular priority are schools that demonstrate they have an at-risk population, as determined by state test results and high poverty numbers or rate. The State Outreach Workshops would take place simultaneously with the Summer Math Academies. The State Outreach Workshops would be led by the PDP/C members and the Academy Trainers.

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Over the past few years, I have been reading books like Collins, "Good to Great", Friedman's "The World is Flat", Pink's "Drive" and Christensen's "Disrupting Class" and considering how they relate to teacher professional development (PD). The content of these books seems applicable as we think about the question "what would it take to design, implement, or assess quality of mathematics PD that would support the implementation of the CCSSM content and practices". For the purposes of this brief, I'm particularly interested in how this literature might inform how we design PD.

"Disrupting Class" focuses on what genuinely individualized education can be like and how to bring it about. We may want to consider how technology, and the new tools it provides us, can dramatically change how we think about and design PD related to CCSSM. Social media tools like Facebook and Twitter, blogs and wikis, Skype and Skype Education, YouTube and Wikipedia are all tools that offer 24/7, anytime/anywhere access to information and interaction. How can we use them to our advantage in PD? What would genuinely individualized PD (learning) look like?

For the past three years, I've been working with EcO_{15} (http://www.eco15.org) an economic growth effort funded by the Lilly Endowment, involving 10 counties in southeast Indiana. The teacher PD has focused on Project Based Learning (PBL). The design of our PD has been evolving and the range of collaborators involved in the design and implementation is growing. For example, the Buck Institute for Education (http://www.bie.org/) has developed a suite of online tools that we believe will be useful in our summer academy time with educators, and also provide participants in our PD ongoing support. Edutopia (http://www.edutopia.org/) provides a wealth of resources in a variety of formats. Cisco is working with us to develop demonstrations of how increased connectivity can increase efficiency and effectiveness of support while lowering costs. How can we take advantage of innovation to design resources for learning related to the CCSSM?

"Drive" by Daniel Pink focuses on what really motivates people. Pink's premise is that we need to upgrade our "Operating System" from one that has been too narrowly focused on reward and punishment, to one that appeals to something bigger inside all of us; our intrinsic need for autonomy, mastery and purpose. How can our PD design develop these in educators? How can we avoid focusing on rewards or punishments related to achievement and focus on the joy that helping people learn can bring? We work hard on things that bring us joy. How can we leverage that to improve student learning?

In the PBL world that I'm currently immersed in, a six-step process is used to support novices in project based learning. The six steps closely relate to many problem-solving processes and perhaps they can help us think about design:

1. Define the Problem (*What is our problem?*)
2. Solution Criteria (*What needs to be in our solution?*)
3. Possible Solutions (*What are possible solutions?*)
4. Choose a Solution (*What solution should we use?*)
5. Run, Solve, and Inspect *(How do we create, run and inspect our solution?*)
6. Evaluate (*Did we solve the problem?*)

I wonder what a PD system that utilized new media would look like and how it would be used? Could the CCSSM be considered a "disruptive innovation" that will provide an opportunity to radically rethink mathematics education and also teacher education/PD?

An Idea

Based on my experiences with bie.org and edutopia.org, and also on my interactions with entities focused on large-scale workforce development, I wonder what it would take to develop new media tools to help educators understand the CCSSM and to support the "implementation" of them? What are the components that such a system should have?

- A safe environment in which practitioners can share, practice and receive support/critique
- Environments in which to both design instruction and "troubleshoot"
- Anytime/anywhere access to resources
- Multiple modes of interaction for learners
- Participation by multiple communities (teachers, administrators, policy makers, community members)
- A continual improvement process
- A means of assessing impact

How does PD using new media/social media "fit" with the National Staff Development Council (2009) entitled, "*Professional Learning in the Learning Profession: A Status Report on Teacher Development in the United States and Abroad*" four basic, research-based principles for designing professional development? Can such PD be intensive, ongoing, and connected to practice; focused on student learning and address the teaching of specific content; aligned with school improvement priorities and goals; and build strong working relationships among teachers? I think it can, but we haven't yet figured it out.

Books/Papers that Have Influenced my Thinking:

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The principles offered by the National Staff Development Council (2009) are a good starting point for the design of a professional development (PD) program to support the implementation of mathematics content and practices in the CCSSM: 1) intensive, ongoing, and connected to practice; 2) focus on student learning and address the teaching of specific content; 3) align with school improvement priorities and goals; and 4) build strong working relationships among teachers. However, research and the experiences of PD providers suggest other factors that will be critical to successful implementation.

- PD should not only be ongoing, but should be long term. Real changes in teacher practice do not happen in a year or even two years (Banilower, Boyd, Pasley, Weiss, 2006); there is no quick fix, as much as administrators, publishers, and politicians would like to find one, and this has to be made clear at the outset.

- To make such changes across the community of teachers, PD by design must confront the expectations and beliefs teachers have about students (Boaler, 2002). Too many teachers in good faith shelter their students from doing real mathematics, the kind expected by the CCSSM.

- Principals are central in successful PD initiatives by making opportunities for teachers to engage in the PD, providing visible signs of support, modeling beliefs about high expectations for all students and creating a school culture that reflects these beliefs, and empowering teachers to put in practice what they learn (Banilower et al, 2006; Education Trust, 2005).

- Parents, families and the larger community have to be part of the process or the changes will be protested and undermined.

- PD providers matter (Banilower, et al, 2006). Not all PD leaders are equal; their training and background make a difference in what teachers learn and take from the experience. A position, whether at a university, within a school district or with commercial PD providers does not automatically qualify an individual (or the program espoused by that individual) as able to support the CCSSM. The community should establish criteria for delivering appropriate PD.

- PD that supports the CCSSM should be focused, coordinated and coherent. Currently, in far too many schools, districts, and even states, competing initiatives are forcing teachers to make choices about which program to follow, or even to shift gears several times in the course of a week (i.e., on line computer practice once a week focusing on a certain set of procedures and strategies, whether or not they coordinate with what teachers are teaching; formative assessments every other week with mandated follow up with yet another set of procedures and strategies).

- Programs should be guided by ongoing formative assessment, where the designers and trainers continually reflect on what seems to be working and what does not, making adjustments and monitoring progress along with outside evaluators who bring new eyes with which to examine the work. The lessons learned about formative assessment in terms of student learning (Black & Wiliam, 1999; Black et al, 2004) should be applied to teacher learning in the context of PD.

Involvement in two NSF MSPs shapes the following suggestions for PD that could successfully support the CCSSM. The work should have three foci: deepening content knowledge, reflecting on teaching practice, and becoming part of a leadership community. The work would begin in a whole state or multiple-district setting to provide contrasting ideas, perspectives, backgrounds that in the end strengthen the program by the very diverse nature of the participants and their school cultures. The necessary follow-up work and support for implementation would be done more locally, guided by trained teacher leaders.

The course on deepening content knowledge should model the CCSSM practices and allow practicing and prospective teachers to "experience mathematics the way a mathematician does" (Matsuura, 2011). The work should engage teachers in:

- performing experiments and grappling with problems,
- formulating testing, and revising conjectures,
- developing theories that bring coherence to observed results,
- expressing understanding using precise language.

Principles guiding the design of activities include: "exposure before closure" where the learner uses examples to build intuition (note this should be interpreted in the sense of the mathematical practices, building intuition then generalizing from patterns in arithmetic and recognizing and using an underlying mathematical structure to solve problems); provide multiple points of entry so all can participate and be successful, emphasize connections and relationships among different problems; repeat problems presented from one perspective (i.e., algebraically) in another (i.e., geometrically); foreshadow key ideas through informal approaches; using technology as a tool for developing understanding (PROMYS, SSTP).

The course on reflecting on practice should be based on emerging research about the value of making teaching public and building communities of practice (e.g., Hufferd-Ackles, Fuson, Sherin, 2004; Horn, 2008), where teachers visit each others' classrooms; together with colleagues, view videos of their classrooms and discuss student learning; collectively design, implement, and observe lessons and reflect on what students took from the lesson. The work should engage teachers in thinking about:

- the tasks they assign,
- the five practices for productive mathematics discussions (Smith & Stein, 2011),
- the role of questioning in enabling learning,
- implementing formative assessment on a daily basis.

The underlying principles include: use artifacts of practice, provide and make explicit theoretical framing for the work, plan for public records of student thinking, build from participants' knowledge and backgrounds, anticipate responses, model desired outcomes, and careful structure of situations that provoke participant discussions.

Developing teachers as leaders can be done through involving selected teachers in the design and delivery of the courses, adapting a lesson study model. The teacher leaders facilitate the courses under the guidance of the project team, meet on a daily basis to reflect on needed modifications, and gradually assume responsibility for the courses.

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The starred references are well worth utilizing in the work designing and implementing PD that supports the CCSSM.

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While it will take many revisions to "business as usual" at all levels of mathematics education from state policies to classroom practices, I believe that there are two particularly critical challenges for retooling the American teacher workforce to deliver on the great promise inherent within the CCSSM, both arising from the Mathematical Practices component of the CCSSM. The first of these challenges is achieving a lasting shift in the beliefs of many within the enterprise of teaching mathematics, to see math as intrinsically a sense-making endeavor rather than an answer-getting undertaking. The second challenge is supporting teachers in knowing what a classroom looks like which is engaged in both successfully teaching for, and implementing robust and on-going assessment of, the Mathematical Practice Standards.

Within these two broad target areas, there are numerous levels of complexity and opportunity to catalyze meaningful change in teachers' knowledge and practice, and by extension in students' learning. Chief among these is the need to continue serving the students who are currently in classrooms. We cannot allow these students to suffer because both fiscal and human capital is being redirected toward serving future students through the implementation of the CCSSM. We also need to support those same students in navigating their own paradigm shift. Many current K-12 students have been so well-educated in the model of mathematics as answer-getting that they cannot help but be confused, frustrated, and perhaps even resentful of being required to radically change the ways in which they interact with the material they are attempting to master.

Despite the work of the two consortia developing the next generation of student assessments, it will still fall to classroom teachers to assess their own students from both a formative and a summative perspective to inform their on-going instructional practices, offer feedback and assign grades to students. In many instances, it will also fall to classroom teachers to design those assessments. Foundational to the ability to even begin this work is the need to have a deep understanding of the standards and what mastery of them will look like when manifested in the context of student work. This task will be most challenging when teachers are attempting to develop metrics and tools to use in assessing the Mathematical Practice Standards. Classroom teachers have struggled to create rich and informative instruments to use in measuring what might be described as traditionally valued aspects of mathematics. The need to measure such content as a student's ability to make sense of problems and persevere in solving them takes the challenge of crafting and interpreting good course assessments to an entirely new level of complexity.

And in instigating the necessary disequilibrium to motivate meaningful change, it is important to remember that the Mathematical Practices do not present a de novo contribution to the work of providing all students with a high quality K-12 math education. They are highly aligned to the National Council of Teachers of Mathematics (NCTM)'s Process Standards and Reasoning and Sense-Making documents along with the Educational Development Center (EDC)'s Habits of Mind. Given that none of these earlier efforts have been universally embraced, there still exists a substantial amount of inertia that will need to be overcome in shifting core beliefs on the part of a critical mass of those engaged in the work of fully implementing all aspects of CCSSM.

In support of meeting these myriad challenges, teachers should experience a two-pronged approach to PD. The first piece should be designed to ensure teachers experience the Mathematical Practices for themselves. Given the median age of today's teaching force, the preponderance of current classroom teachers may have never experienced mathematics taught for understanding in either their own K-12 math learning or their teacher preparation program. Without a visceral experience to anchor their learning about the Mathematical Practice Standards, they are unlikely to experience deep change in either their thinking or their classroom instructional practice; any change that does occur is also less likely to prevail over time. This component of the PD might be best achieved through a week-long institute model, where teachers are themselves asked to serve as learners of the mathematics they will teach, but examined at a deep level with an emphasis on the Mathematical Practices. This learning experience would be coupled with a highly focused debrief of how the teaching that has just been experienced by the participants caused them to interact with the content in significantly different ways than they have traditionally asked of their own students. This piece then would offer the necessary intensive introduction to what the Mathematical Practice Standards would look like within a classroom setting.

The second prong of this approach would be based on a type of lesson study model, but with modifications allowing the idea to be taken to scale with teachers at a variety of places along the engagement continuum. Teachers would work collaboratively in grade-level teams to engage in careful examination of assessment of specific grade level content standard coupled with the Mathematical Practices. The work of the team would include determining what would constitute evidence of student learning, an appropriate sequence of items within the assessment providing a low threshold so that all students have the opportunity to show what they know, but a sufficiently high ceiling so that it is also possible to ascertain what they have not yet mastered. The study would include the crafting of a common assessment, use by all the team members, shared examination of the student work and design of next steps in response to the outcomes. A second cycle would be to take the lessons learned from this collaborative process and apply them to a new grade-level standard.

These teams might include teachers from more than one school, depending on the size and geography of the district. It would be important in the first cycle to offer the opportunity for everyone to be fully involved while also recognizing the range of readiness on the part of teachers. There will always be early adopters; individuals seeking ways to refine their instructional choices to realize a greater impact on student learning. While these individuals can be marginalized within their departments or schools if their values are not aligned to those of the predominant school culture, they also can serve as the fulcrum for leveraging the influence of PD programs. These early adopters should be used as the team leaders in the first cycles of this process. A modified lesson study would also allow for more reluctant teachers to participate at a less intense level, though it is important for them to have an ongoing responsibility within the process over time to begin to increase their engagement with instructional change. The team should be provided a significant and well-defined time period in which to accomplish their work, whether this is done by rearranging the school bell schedule or their teaching assignments so that they coincide in support of this effort. It cannot be the responsibility of the teachers to carve out the necessary time to engage in this work. Neither should they be required to extend their work day to accommodate collaboration. If the study teams are to make even incremental change, they require structural support from administrators.

The last important contribution that can be made by any district or state engaging in a comprehensive professional development around the CCSSM, is to better disseminate their findings. This could be done at an anecdotal or action-research level without attempting to comply with the gold standard criteria defined by the National Math Panel as a means for broader and faster distribution of lessons learned. And if we are to maximize the benefit from the work being done throughout the country, hopefully instances of failure would be included. We stand to learn most from looking at programs which appeared to be doing everything correctly, yet fell well short of their stated goals. As a mathematics teacher, I am constantly advocating for students' close and careful examination of their errors as a particularly powerful learning tool. Given that perspective, how can we ask anything less of ourselves?

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California Mathematics Project

Challenge 1: The existing accountability systems and the misunderstandings of accountability and assessments are not compatible with the CCSSM. Previous state standards have been driven by accountability systems that only measure students getting multiple choice questions correct, hence daily pacing guides to ensure coverage and test practice have evolved as the dominant instruction form. Problem solving and conceptual understanding, and other mathematical habits of mind, i.e. CCSSM practices, (being difficult to reliably capture in multiple choice formats) have been greatly de-emphasized.

What is needed:

I think the most critical need is for an accountability system that emphasizes mathematical accomplishment throughout the year versus student achievement on end-of-year exams. The new assessment consortia will hopefully help, but there needs to be something else de-coupled from the state/national accountability instruments. We need a system that puts authority of judging students mathematical character into the hands of the teachers.

Challenge 2: Pedagogical Changes. The CCSSM are significantly different in design than previous state standards. Hence "crosswalk" or "swap-out" approaches (i.e. relabeling or indexing previous state standards with the CCSSM) will not be helpful.

What is needed:

We need professional development (PD) that helps teacher plan units, look for evidence of student understanding, and looks for evidence of mathematical character, a la the mathematical practices. We need to work with principals and administrators to make sure they realize that scripted curricula and daily pacing guides are not compatible with the CCSSM. Students do not learn in lockstep.

Challenge 3: New Mathematical Content. Certain areas of the CCSSM will be new or unfamiliar content to most teachers.

What is needed:

PD focused on Transformational Geometry, Fractions on the Number Line, Mathematical Modeling, Probability and Statistics. These topics seem most in need of attention. Another need here is that teachers and administers often think they already know the mathematics. Hence closer looks at the CCSSM are needed to make sure these ideas do not fall through the cracks.

One Idea for Scaling Professional Development

My idea how to do PD to scale is to focus on principals and administrators (school or district people responsible for curriculum, benchmarks, assessment, etc.) They need to understand and see what good mathematics looks like. Checking to see if the standard of the day is on the board is not good.

Since there are projects started like the Illustrative Mathematics Project and others creating example of activities, student work, videos, etc. already, I think there needs to be PD for administrators to learn about those resources and how to support their teachers in finding and using those resources.

There should be PD designed to connect administrators with a national network of other administrators. I imagine a FAQ-type resource. E.g. there will be several questions that come up over and over: what are going to do about pacing guides? What about tracking? How do kids prepare for performance assessments? My teachers aren't familiar with the math, where can I get support?

My feeling is that there is a tremendous amount of district-level reinventing of the wheel. Small schools, big districts, they are all trying to figure out: "how do we deal with these new standards?" This is a case where *scale can be helpful*. The challenge is how to aggregate and communicate the various ideas and feed them back to the system.

This needs to be a combination of site-based, face-to-face work and on-line resources. I am also open to the use of communication technologies, like skype or others to allow discussions to occur across long distances. It is essential to make use of these *weak ties* (Granovetter) and build an *affinity space* (Gee) for administrators.

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Marta Civil

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I will begin by "positioning" myself in terms of my experience with this topic and my research expertise, so that my remarks can be seen through this lens. I am primarily a user of professional development (PD) materials; that is, in my work with teachers I use resources developed by others. I am not a PD developer and large-scale PD is not my main focus of research. I have done research with Teacher Study Group (TSG) formats. We engage with the teachers in looking at students' work as well as in doing mathematics ourselves. Crucial to this approach is the concept of reflecting on practice. A further focus of our TSGs is on the role of language and culture in the teaching and learning of mathematics. This focus is directly tied to my research expertise, which in general terms, I will describe as equity in mathematics education. What I bring to this meeting is my expertise on equity. The CCSSM document does not really address this topic, other than with two short documents "application of the standards for English language learners" and "application to students with disabilities." These documents apply to both the English language arts and the mathematics standards; they are not integrated with the CCSSM document that most teachers (at least in my local context) are familiar with.

I would like to raise some questions to be considered as we think of "designing, implementing, **or** assessing quality of mathematics PD that would support the implementation of the CCSSM content and practices."

What, if anything, is different in CCSSM that may call for a different form of PD that successful programs would not be able to address? Are there models in place that could be scaled up?

Are there challenges / opportunities posed by CCSSM that current efforts in PD do not address?

What are the mathematical concepts that are likely to be different from previous efforts? For example, in fractions key ideas are unit fractions and fractions as numbers on the number line; in geometry (grade 8), there is an emphasis on transformational geometry. One aspect of CCSSM is more in-depth treatment of fewer key concepts; some of these concepts may be unfamiliar to some teachers (depending on the state). We need models, tools, artifacts to illustrate the standards for mathematical practice. Teachers in one of my TSGs wrote "clearly define /model 'mathematical practices'" as they found the definitions / descriptions in the CCSSM too vague. I would like to focus on two of the mathematical practices from an equity point of view:

3) Construct viable arguments and critique the reasoning of others: PD around this practice needs to address the sociocultural (including language) context of the students; there are potential issues of status involved, as well as different views on what it means to argue and to critique and what is acceptable, culturally (for example, the work or Roberta Hunter with teachers of Maori and Pasifika students in New Zealand to develop an approach to teaching mathematics that engaged these students in argumentation; Hunter (2010) describes some of this work).

6) Attend to precision: What are the implications of this standard (and of the previous one, #3) for working with ELLs?

Finally, from an equity point of view, I do want to draw attention to the CCSSM emphasis on standard algorithm…. What does that mean? Standard for whom? In my research with parents and children of Mexican origin the issue of different approaches (algorithms) for arithmetic operations often comes up. What is the role of PD developers in addressing standards such as...

4.NBT- 4. Fluently add and subtract multi-digit whole numbers using the standard algorithm.

5.NBT – 5. Fluently multiply multi-digit whole numbers using the standard algorithm.

6.NS - 2. Fluently divide multi-digit numbers using the standard algorithm

...while respecting the diversity of algorithms that students are likely to know, invent, etc.?

Next I try to address the second issue "describe, in some detail, one idea you have for how PD can be done at scale (i.e., with a whole district or an entire state) to support the implementation of the CCSSM." I do not think I really have one idea, but more a set of issues brought up in conversations with professional developers in a large district in Tucson and with a group of teacher leaders.

1) Opportunities to engage in mathematical thinking in an environment that reflects standards for mathematical practice.

2) At least in the beginning, need to attend to the tension between the immediacy of having to implement CCSSM while allowing for 1) to happen.

3) Time for teachers to compare /contrast CCSSM with local state standards and identify changes.

4) Possibly, a multi-year effort with a cohort (n =90 teachers K-5) summer and school year (split in smaller TSG/ learning communities during the year) -> this means only a few teachers per school (maybe as few as two), but there is the expectation that these teachers will do PD at their sites and other sites with colleagues.

5) Some of these schools become demonstration sites that other teachers can visit.

6) PD should be teacher-driven, based on school existing learning structures.

7) PD should be embedded with research (e.g., effective practices; students' learning) and involve teachers in action-research.

8) PD should focus on: teachers learning how to listen to students and understand students' learning; teachers creating spaces to reflect on their own learning and practice; teacher becoming inquirers.

9) Developing a tool that would allow teachers to self-assess their understanding of the mathematical CONTENT in the CCSSM to then know which areas they need to work on.

10) Online site to post lessons that address common core; wiki to post and discuss concerns and issues. The fact that the standards are common was seen as an opportunity for teachers across states to be able to share experiences; teachers from a smaller, rural district were particularly interested in this since they often feel isolated / have less access to resources.

11) However, once concern with the common side of CCSSM is that States do not have common educational policies. For example, language policy for the education of ELLs varies across states. What may be the implications of a common core (and assessment) when the conditions are not common?

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In graduate school, I read a manuscript (Green, 1983) which has been helpful to me in thinking about the prospect of improving the education system. The manuscript took on difficult and infrequently discussed issues such as equity, equality and excellence. I continue to carry with me lessons I learned from the manuscript, including:

1) Policy is a blunt instrument for social change;
2) Public “goods” are in constant conflict – policy often seeks to maximize competing goods – the pursuit of joint goods of equity and excellence can be hindered by levels of aggregation (scale-up) and by problems of implementation;
3) If we want to attain equity, it is best achieved through attaining excellence – whereas the pursuit of equity is not likely to lead to excellence; (Note: though excellence remains undefined, I equate it to conceptual understanding in teaching and student learning)
4) When societies feel threatened (e.g., perceive educational or economic decline), leaders are willing to “replace maximums with minimums, talk of excellence with talk of elementary basics;”
5) “The path of public policy [excellence] best designed to satisfy our yearnings for equity is the one path we have studied least and debated hardly at all.”

What I continue to find important to reflect on is the last statement – I marvel at how little we know as a field about teacher practice. This includes descriptions of modal practice, as well as thoughtful descriptions of “excellent” or even preferred practice within the disciplines. Why is this particular manuscript from my graduate school experience relevant for thinking about professional development (PD)? For starters, I think the idea of replacing maximums with minimums is precisely where we find ourselves in the current policy realm. Standardized test scores on state tests (and potentially estimates of teaching quality derived from them) drive an accountability system, while the CCSSM attempt to push teaching and learning toward fewer, clearer, and higher goals in education. The standards attempt to clarify what “excellent” practice entails, but more specific guidance will be required.

My experience researching Comprehensive School Reform programs (e.g., Correnti and Rowan, 2007; Rowan and Correnti, 2009; Rowan, Correnti, Miller and Camburn, 2009), reading the literature on efforts to change behavior at-scale (e.g., Elmore, 1996; Nunnery, 1998) and examining PD effects on teacher practice (Correnti, 2008), all converge on the need for specificity to influence professional learning. This follows from my own assumptions that learning results from interactions between students and teachers over instructional materials – i.e., content (Cohen and Ball, 1999; Harnischfeger and Wiley, 1976). It also follows from my own beliefs that optimal learning is socially constructed and adult learning theories should parallel student learning theories (e.g., Stein, Smith and Silver, 1999). All of this overlaps with #2 of the four basic research principals – *professional development should focus on student learning and address the teaching of specific content.*

The first thing it takes, therefore, to design successful PD is coherence around normative practice (Elmore, 1996). This is the number one problem to be solved and is why my idea is to scientifically research specific aspects of mathematics practice. This has multiple functions including:

1) Understanding modal practice – including establishing a baseline of practice from which we need to move from
2) Identifying successful instructional profiles – including creating a vision of what kinds of instructional behaviors we want to inculcate in schools
3) Creating a common vocabulary so that leader-teacher dyads and teacher-teacher dyads can effectively communicate about practice (the vocabulary also extends to professional learning communities)
4) Develop a measurement system to make teaching goals more concrete and to mark progress toward teaching goals

My colleagues and I have spent some time thinking about the how the scientific study of teaching can be integrated with what we know about effective PD. It is our intention to simultaneously study practice while thinking about methods for creating and extending ongoing work on development.

One core principle of this work is that we have chosen to focus on a single element of practice—discourse. This strikes us as important because it is narrow enough to begin to measure, and because discourse overlaps with many other aspects of teaching. For example, the mathematics task chosen by a teacher is likely to be related in important ways to their discourse, as well as the assignment and student work resulting from the task/assignment. Additionally, discourse may interact with other important design choices in mathematics such as the topic (or thread of the curriculum) and it is also likely related to teachers' epistemological belief structures. In this way, some might consider discourse to be a high-leverage teaching practice because it is a gateway for discussing multiple aspects of teaching.

A second core principle is the idea that we can generate an objective record of teaching which can lead to concrete discussions. Our goal is to create a visual representation of discourse. This picture would then form the basis for these discussions, complete with a shared vocabulary. This discussion could help illuminate the current state of practice, as well as contribute to discussions about what idealized practice could look like. The hope is that teachers would reflect on how they can improve their discourse practice and that this might generalize to other aspects of their teaching.

At the very least, our hope is that the measurement of teaching will push us forward on an agenda for being able to debate "excellence" (Green, 1983) and/or develop strong external normative structures for practice (Elmore, 1996). Lacking the ability to establish a target for teaching change it is difficult to imagine how external structures can support professional learning. If the literature on reform implementation has taught us nothing else, it is that teachers are policy brokers and require a high degree of specificity in order to generate changes in their practice.

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Designing quality professional development (PD) for mathematics teachers will require a qualified design team of both mathematicians and educators. This design team would need to have a variety of experiences working with classroom teachers. Experienced classroom teachers feel like they know the content and pedagogy that works best for their students. Thus, working with classroom teachers is different from the work involved in preparing future teachers. The material developed by this team should address both mathematical content and pedagogy for teaching this content. Since this PD will be offered to classroom teachers, evidence of the success of the CCSSM should be shared with this group. Teachers need to be motivated to learn more about implementing these standards in their own classroom.

If the PD workshops are to be successful, the teachers need to WANT to attend. Also, ALL teachers in a school district should attend the PD if the CCSSM are to be implemented successfully. These are both critical in my opinion and one of the biggest challenges. Determining how to entice teachers to come back and learn new content and new pedagogies is extremely important. The workshops should be conducted in a way that supports and encourages the teachers involved. The CCSSM encourage teachers to teach for understanding and this may be an adjustment that some teachers will need to make in their classroom. Therefore, in addition to increasing the teachers' content knowledge, the teachers need to be challenged to change what they expect of their own students and the methods they use to access their students.

In my opinion, the content and purpose of the PD workshops would be different for teachers of grades K-5, 6-8 and high school. Some specific concerns for K-5 stem from the fact that these teachers typically teach all subjects. Their training trained them for a variety of subjects so they may not have extensive backgrounds in mathematics, nor the time to devote to teaching their mathematics courses that most middle and high school teachers have. If the ultimate goal is to get students excited about mathematics, their teachers must be excited about both doing and teaching mathematics. Attitude, as well as content knowledge, will need to be addressed. Some K-5 teachers do not feel that mathematics is one of their strengths, so their confidence in their own ability will need to be strengthened. A successful professional development workshop will need to develop the mathematical practices of the CCSSM in the teachers, in order for the same practices to be developed in their students.

Middle school teachers (grades 6–8) are a more diverse group than K-5 teachers. The certification of teachers at this level will vary. In some states, teachers are certified K-8, in some states 7-12, and in others 6-8. The result is that the preparation and content knowledge of middle school teachers is varied. While all of the teachers would need to learn the new standards set forth in the CCSSM, some of them will be more able to teach these topics than others. The PD workshop should provide the teachers with an avenue to learn new content, as well as new methods.

For both of the above mentioned groups the mathematical preparation will vary widely, both in the number and types of courses. For example, some universities offer mathematics content courses developed specifically for future K-8 teachers, and some do not. Also, the number of mathematics courses required for these teachers can vary from one school to another. In addition, many of these courses did not require that the students demonstrate true understanding of the processes they will teach. Thus, some of the teachers may not understand the process behind many of the algorithms they teach. A successful teacher needs a variety of tools to teach each topic, and the PD workshop is an excellent opportunity to help these teachers add to their tool belt.

The preparation of high school teachers tends to be more standard with guidelines given by NCATE and MAA (Mathematical Association of America). However, these teachers may need help with pedagogy, as did their peers in grades K-8. With the number of new teachers choosing teaching as a second career and seeking alternative certification, this is an area of concern. Thus, the workshops developed for these teachers again need to focus on issues of both pedagogy and content. Also, since technology is more prevalent in high school, the workshop should include how to use the current technologies, with focus on when these technologies are appropriate.

If teachers are to prepare students who will truly be able to understand and demonstrate their understanding, then the teachers will need to develop these traits as well. In order for PD to achieve these goals, it must be intense, both in terms of content and time. PD will need to take place face-to-face, and will need to model the standards and practices the teachers will be expected to implement in their own classroom. These workshops should create an environment where teachers feel free to risk being wrong. The teachers will need to feel comfortable and valued throughout. The workshops need to be ongoing and should start with an intensive event, lasting from one to four weeks, with additional follow-up meetings during the year.

Implementation and assessment of PD are also major concerns. In my opinion, implementation should not take place larger than at district level for concerns of continuity and community. Also, assessment should address not just content learned, but teaching methods that were carried back to the classroom. A successful PD workshop should change not only WHAT is taught, but HOW it is taught. The assessment plan should incorporate this.

When developing PD for an entire school district, there should be separate events for teachers in the above mentioned grade bands, K-5, 6-8 and high school. Each group should have an initial workshop of no less than a week. This workshop should allow teachers to build a community of learners where they feel safe taking risks. Within this initial workshop, part of the time should allow the teachers to break into grade-level groups to discuss common issues. However, at times, all grade levels in that group should gather together so that each grade level is aware of what takes place at other levels so they can see common ground. After the initial workshop, teachers at one school location should have a common planning period to meet together, at least by grade-level, and sometimes as a whole group. Periodically during the year, the teachers should be allowed to gather back into their original groups. Ideally, this would take place monthly, but that may not be feasible.

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My thoughts address what it would take to design and implement high-quality mathematics professional development (PD) that would support the implementation of the CCSSM content and practices, with a particular focus on elementary school teachers. In putting together these thoughts, I draw on ten years of experience as Director of Elementary Mathematics for the Boston Public Schools, as well as several years of experience collaborating with the QUASAR Project while at Portland State University and several years collaborating on and co-directing NSF-funded PD projects at the Education Development Center. My experience with Boston Public Schools includes designing and implementing PD at scale. While all of these experiences predate the CCSSM, the goals of these efforts address (and continue to address) helping teachers construct a mathematics teaching practice that focuses on reasoning and sense making and the development of important mathematical proficiencies for the elementary grades. I address what I think are important considerations below, discussing what we have learned through our work thus far, and with attention to the implications of the CCSSM and the question of scale.

1. **Deepening the mathematics content knowledge of teachers, providing experience with the practice standards, and preparing teachers to understand the mathematical thinking of their students.**

There is a good deal of research suggesting that the mathematics content knowledge of many elementary teachers is superficial and procedural. In order to be prepared to teach the CCSSM and practice standards, teachers need to both deepen their conceptual understanding of elementary mathematics content in ways that allow them to also experience the mathematical practice standards. This is particularly the case where elementary teachers are expected to address new content (e.g., the conceptual foundations for multiplication and division with fractions). In addition, we find it essential for teachers to have opportunities to examine and discuss how students are likely to think about this content, especially given how much of students' mathematical thinking is likely to emerge as they engage in the CCSSM practices. Considering student approaches, discussing how these are similar to or different from their own approaches, and investigating what the work suggests about what students understand or where they struggle also contributes to the deepening of teachers' own understanding of that content as well as preparing them to hear and make sense of what is likely to come up in their own classrooms.

While much of the research on effective PD suggests that school-based contexts may work best, we have found that working on mathematics and students' mathematical thinking together in any kind of cohesive way is difficult to do in the limited chunks of time typically available during a school day. Elementary teachers seem to need extended opportunities to deeply immerse themselves in examinations of this mathematics over extended periods of time, for instance, during consecutive full days during the summer or over a set of Saturdays during the school year.

While much of the work examining and learning mathematics takes place through small group investigations, as well as through whole group discussions, we have found it important to find ways to uncover what each participating teacher is thinking and learning. For that reason, we find it important to assign homework, where teachers are expected to solve problems on their own that revisit and extend what they are learning in their PD. We have also found it important to design "exit tasks" for the end of every PD session where the facilitators of the PD get some immediate information about what teachers are learning and where they may still be struggling. It is important that homework problems and exit tasks not be procedural or routine but address underlying conceptual understandings and involve the use of important models and representations.

When working to scale, we have also found it important, to have a specified set of PD offerings that everyone participates in over time, that these are all of high quality, and that there are clear norms and expectations associated with each of the offerings. For instance, in Boston, we have an identified set of facilitators of the *Developing Mathematical Ideas* seminars that we offer; we meet regularly with these facilitators to ensure they are clear on learning goals for participating teachers overall and for each session and have thoughtful strategies for assessing what participants are learning; we set norms about how co-facilitators plan together for each session, as well as how they handle exit tasks and homework[1] ; we are clear that all sessions are to be the specified length with no one getting out of sessions early or skipping breaks or working through lunch; we discuss how to make it clear that homework is expected of all participants and participants who do not thoughtfully complete their homework in a timely way have a serious conversation with the facilitators about what it means to be a committed member of that learning community. In addition, we often visit sessions to see how they are going or examine the written work from sessions to see what participating teachers are submitting for homework and how co-facilitators are responding. We have found that all these efforts reduce any crankiness or complaints about participating since the same high expectations are clear for all who participate. This also creates a shared learning experience that cuts across the district.

In the interest of reaching all teachers, we design PD schedules to meet a variety of needs and constraints—Saturday sessions, summer sessions, three-hour after school sessions, and sessions during the school day with substitute coverage. The school day offerings come with a variety of challenges. One has to do with the difficulty of being out of one's classroom regularly over some period of time.[2] Another has to do with how teachers are compensated for the time they spend doing homework. We have addressed this second issue by providing stipends for the additional time expected for completing homework assignments. Sessions held outside of the school day are stipend at a rate equivalent to the cost of a substitute plus a bit more for homework. We find that teachers who do not do their homework, or who otherwise do not come prepared to our PD sessions, do not seem to learn as much as those who do, and for that reason, we find it essential to sort out with teachers and their teacher union how compensation for both attending the PD and doing any outside work associated with the PD is determined.

2. Supporting elementary teachers as they construct a new mathematics teaching practice.

While teachers may learn a good deal by participating in PD, there are no guarantees that this learning will shape or strengthen their mathematics teaching practice on a daily basis. This is where school-based PD plays an important role. By school-based PD, we mean teachers working together during grade-level team meetings to plan and debrief lessons and look at student work, teachers visiting each other's classrooms using structured protocols for such visits, teachers engaging in "learning walks" to collect information on mathematics teaching and learning in their buildings, teachers co-planning and co-teaching lessons, and the analysis of student data with discussions of implications for instruction. All of this school-based PD is more powerful if a well-qualified and well-prepared mathematics coach who is intimately acquainted with the district-level PD (and perhaps even facilitates some of it) is available to plan and facilitate these activities with teachers. It also helps if the instructional materials and assessments adopted by the district are consistent with the goals and vision of the CCSSM content and practice standards. One of the significant challenges associated with the school-based PD has to do with access to teachers. In many districts, there may be only one common planning period per grade level per week, which often also needs to be shared with those supporting ELA and literacy, especially given the CCSSM addressing those areas.

Finding ways to release teachers from their classrooms on a regular basis may be important in order to this work to have impact over time. Here, too, the notion of a "math brigade" footnoted below can be useful.

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[1] Co-facilitators respond in writing to each homework assignment from each participating teacher. These responses are about a page in length and address strengths as what might be strengthened in the work. These are also opportunities to comment on what participating teachers share about their thinking or how they engage with colleagues during the PD session itself, create an opportunity for a personal conversation with each participating teacher about his or her learning, and help build a commitment to the professional learning community that is being created. While all of this takes considerable time, we have found it well worth the effort.

[2] One urban district in our region has created a "math brigade" of substitute teachers well prepared to teach mathematics lessons to students while teachers are out of their classrooms. (For elementary teachers there are also issues of instruction in the other content areas but none seem as problematic as mathematics instruction.) This is also a model that might be usefully applied to the release of middle school and high school mathematics teachers.

3. **The role of principals and other school administrators in setting high expectations for mathematics teaching practice in their buildings and in the district.**

We have found it to be essential to have all teachers in the district involved in the PD efforts discussed above, and the extent to which this is effectively communicated teachers depends on principals, as well as central office administrators including those associated with the Offices of Special Education and English Language Learners as well as Curriculum and Instruction. It also depends on messages communicated by the Superintendent, the Chief Academic Officer, Academic Superintendents, and any others who play a role in evaluating and supporting principals and their teachers. Unless school and district administrators successfully communicate that *all* teachers of *all* students are expected to be engaged in this significant and challenging work, there is likely to be resistance among at least some pockets of teachers, or there are likely to be some students not served by this effort. Not having all teachers in the district involved in these PD efforts can also make any school-based efforts less effective, undermines the extent to which teachers are able to successfully collaborate to strengthen their mathematics teaching practice, and can even result in the marginalization of teachers who are making progress because others feel threatened by that progress.

We have found it to be essential that principals and other school and district administrators understand and express support for the very challenging and complicated work teachers may need to do to reconceptualize what it means to teach and learn mathematics and develop new professional identities and practices based on these reconceptualizations. These administrators can express support by participating thoughtfully in some of the PD with teachers, visiting classrooms in order to learn more about teachers' progress enacting what they are learning, providing time for teachers to collaborate, and expressing appreciation for all teachers are doing to strengthen their mathematics teaching practice. This also includes having difficult conversations with teachers who are resisting these efforts, either because they are holding on to old beliefs, have lower expectations for some populations of students, are not willing to make the commitment it will take to engage in these efforts, or are fearful of the work ahead. Unless these messages are conveyed district wide, teachers who seek to avoid these efforts will seek out schools where this work is not required, and teachers who are in these schools will leave to join faculty where there is a strong commitment to the work. Such dynamics create unfortunate consequences with regard to what all students have opportunities to learn.

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MAA American Mathematics Competitions

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Our large-scale survey results document that even the most engaged and top teachers at the best schools report that standard mathematical topics addressed in the CCSSM are harder than their current curriculum. Student performance outcomes on mathematical questions corroborates the results. These findings support the need for professional development (PD) to improve teacher understanding and student performance on these topics.

1. Survey Results

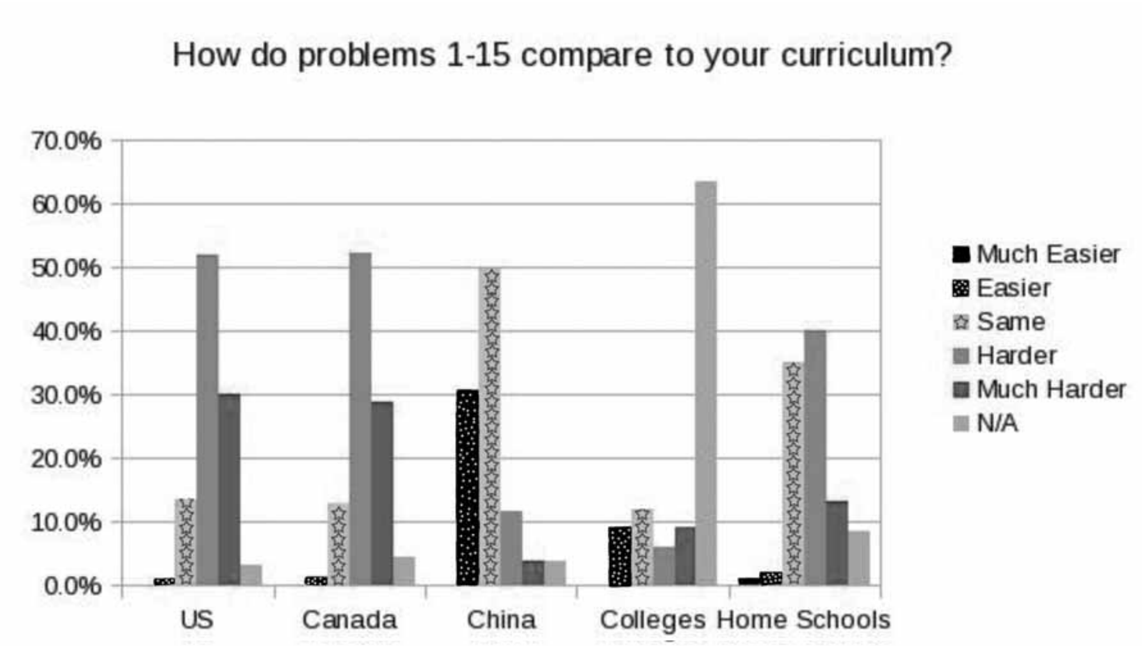
In February 2011, in conjunction with the largest and oldest mathematics competition in the US, the American Mathematics Competition program of the Mathematical Association of America conducted a survey of school contest managers. From 3,931 public and private schools in the US, we collected 2,405 responses, a response rate of 61%. We also received responses from smaller numbers of schools in Canada, schools in China, colleges and home schools in the US which serve for contrast and comparison. This was not a scientific survey, since the participating teachers were not randomly sampled, nor is the sample stratified. It is a sample of opportunity from engaged and high performing schools. However, the survey is large and comprehensive, with responses from all 50 states and from an important sample of teachers.

With the mark-sense forms the students use to answer the questions, we also distribute a mark-sense "header form" for the teacher to fill with school identification information. This provides an opportunity to simultaneously administer a quick 10-question survey of the teachers using a 6-point Likert-like response scale. Then while scoring the competitions, we simultaneously collect and tabulate survey results. For this report, I will focus on only one of the survey questions, the other questions are directed toward marketing and contest administration.

The schools are generally located in reasonably affluent areas of US urban centers. Some schools are in rural or small-town districts. Some are "magnet" or "focus" schools, and some are private schools. Generally speaking, the teachers teach AP Calculus, AP Statistics, advanced algebra, fourth-year mathematics, "differentiated mathematics" or "gifted and talented students".

The survey question was: "Rate the difficulty of the AMC 10 and AMC 12 problems 1-15 compared to the difficulty of your mathematics curriculum." The possible responses were (0) Much easier (1) Easier (2) About the same (3) Harder (4) Much harder (5) not applicable. The results are below in both tabular and chart form:

	Much Easier	Easier	Same	Harder	Much Harder	N/A
US	0.1%	1.0%	13.6%	52.0%	29.9%	3.4%
Canada	0.0%	1.4%	13.0%	52.2%	29.0%	4.3%
China	0.0%	30.8%	50.0%	11.5%	3.8%	3.8%
Colleges	0.0%	9.1%	12.1%	6.1%	9.1%	63.6%
Home Schools	1.0%	1.9%	35.2%	40.0%	13.3%	8.6%



The survey results from February 2011 show that more than 80% of responding US teachers say that questions 1-15 on the AMC contests are either harder or much harder than their curriculum. Next, I will show the hardest questions from that set of contest questions and connect them with the CCSSM.

In addition to the public and private schools in the US, we also administer the contests in Canada, China (and 33 other countries) and in colleges and home schools in the US. Smaller numbers of teachers answered the survey from these categories. The survey responses appear in the table and chart above. It is noteworthy that the survey results from Canada are almost the same as the US, but the results from China are complementary.

2. The AMC Contests

The AMC contests are the oldest (administered annually since 1950), largest (now administered in over 4,500 schools in over 35 countries to about 220,000 students) extra-curricular STEM competition in the US. The content is pre-calculus mathematics, including arithmetic, estimation, percents, everyday applications, algebra, combinatorics and discrete math, geometry, number theory, logarithms and exponentials, trigonometry and trigonometric functions, and complex numbers. The format is 25 multiple-choice questions for students to answer in 75 minutes. At the high school level, we have 2 contests, the AMC 10 intended for students in grades 9 and 10, and the AMC 12 intended for students in grades 11 and 12. In order to accommodate school schedules, we offer 2 contest dates, with different questions on each date. About a dozen questions are shared between the AMC 10 and the AMC 12 on a given date.

University and college mathematicians create the problems with some suggested problems, editing, and review by highly able and experienced secondary-level teachers. The educators and mathematicians on the problem and review committees choose problems for their inherent interest and content. The committees do not choose problems as a representative slice of any curriculum.

The committee intends that the first 5 questions should be easily answered by almost all students, and that the last 5 questions should be very hard and answered only by a few students. The remainder of the questions should gradually increase in difficulty from these two extremes. Note that the survey only asks about questions 1 to 15, not the hardest questions.

3. How these Problems Connect to the Common Core

The AMC publishes many statistical results from the contests on-line at http://amc.maa.org/amc1012/2011/stats/11-HS-StateStats.shtml. The hardest questions on the February contests, measured by having the least percentage of correct answers and the greatest percentage omitted were:

AMC 10 A, Problem 11: (28.6% correct, 47.83% omitted) Square *EFGH* has one vertex on each side of square *ABCD*. Point *E* is on $\overline{AB}$ with $AE = 7 \cdot EB$. What is the ratio of the area of *EFGH* to the area of *ABCD*?

AMC 12 A, Problem 14: (26.6% correct, 26.8% omit) Suppose *a* and *b* are single-digit positive integers chosen independently and at random. What is the probability that the point (*a, b*) lies above the parabola $y = ax^2 - bx$?

AMC 10 B, Problem 13: (9.01% correct, 70.75% omitted) Two real numbers are selected independently at random from the interval [-20, 10]. What is the probability that the product of those numbers is greater than zero?

AMC 12 B, Problem 14: (10.9% correct, 67.5% omit) A segment through the focus *F* of a parabola with vertex *V* is perpendicular to $\overline{FV}$ and intersects the parabola in points *A* and *B*. What is $\cos(\angle AVB)$?

Each of these questions has direct connections to the CCSM:

AMC 10 A, Problem 11: Standard G-SRT: Similarity, right triangles and Trigonometry

AMC 12 A, Problem 14: Standard S-CP: Use the rules of probability to compute probabilities of compound events in a uniform probability model and Standard G-GP: Translate between the geometric description and the equation for a conic section.

AMC 10 B, Problem 13: Standard S-CP: Use the rules of probability to compute probabilities of compound events in a uniform probability model.

AMC 12 B, Problem 14: Standard G-GPE: Derive the equation of a parabola given a focus and directrix and Standard F-TF: Use special triangles to determine . . . the values of . . . cosine.

4. Summary

An overwhelming majority of even the better-equipped teachers at the best-supported schools report that topics on the AMC contests which are directly connected to the Common Core standards are harder than their current curriculum. Student performance on these topics is correspondingly low. The need for change is clear.

Linda Cooper Foreman

Teachers Development Group

Designing professional development (PD) that simultaneously embodies NSDC's recommendations (2009), supports high-quality implementation of the CCSSM content and practices, and has potential for sustainable implementation at scale, calls for the development of a *well-defined school-based mechanism for institutionalizing a culture of mathematics professional learning that is guided by a clear, research-based vision of how students learn mathematics.* This mechanism must enable K-12 teachers, principals and district office administrators to continuously improve mathematics instruction and student achievement, and it must include the following *well-defined, well-detailed* features:

- specific school- and district-based roles and responsibilities,
- professional learning experiences for the individuals in those roles,
- tools/structures for sustaining such roles, responsibilities, and professional learning,
- tools/structures for school-to-school/district-to-district dissemination of the mechanism

In addition, this mechanism must be grounded by a research-based theory of action that includes –

How Students Learn Mathematics. Students understand and achieve in mathematics when they engage consistently in evidence-based learning experiences that involve:

- Cognitively demanding mathematical tasks
- Adherence to mathematically productive classroom norms, relationships, and practices/ habits-of-mind
- Mathematical discourse that focuses on students' mathematical reasoning, sense-making, representations, justifications, and generalizations about important math ideas
- Metacognition and reflection about their own and each other's mathematical thinking

Specialized Mathematics Content Knowledge. In order to orchestrate mathematically productive, high-cognitive student discourse about CCSSM content and cognitively demanding tasks, teachers need a deep understanding of the mathematical knowledge needed for teaching the content, and they need to learn through personal engagement in the CCSSM practices.

Generative Learning. When teachers and administrators attend relentlessly to understanding students' mathematical thinking, and when students attend regularly to their own thinking and relationships to others' ideas, learning becomes self-generating for the students, teachers, and administrators.

Formative Assessment. When teachers inquire continuously to understand students' thinking and use that information wisely to inform teaching decisions, they engage in a practice proven to narrow the gap between low and high achievers while raising overall achievement.

Public Rehearsals and Analyses of Teaching and School Leadership. Publicly planned and coached rehearsals of mathematically productive teaching practices promote fidelity of implementation and the development of a professional community with features that tie positively to student achievement.

Powerful Leadership. The need to reach every student with effective mathematics instruction every day requires the school to be the first order "unit of change," necessitates a distributed approach to mathematics leadership, and calls for the principal as lead learner for mathematics. Specialized learning for principals needs to focus on developing their leadership voice for mathematics, organizing their school for mathematics learning, and analyzing mathematics teaching. Working at scale in a district also requires specialized learning for district office administrators who provide leadership for principals. Reciprocal accountability is a fundamental of all levels of the system.

While PD design and leadership typically come from an external provider, and external providers may always be needed to inject new challenges, local leadership always provides guidance in adapting the design to the system's special needs and other initiatives, and institutionalization always involves a plan for sustenance through the development of local leadership for mathematics.

The Mathematics Studio Program is a model that shows potential as a mechanism with the above design features. Originating from lessons learned during a five-year MSP Institute Partnership, the Studio design has continued to evolve through implementation during the past three years in 25 rural, inner-city urban, and suburban districts from six states. Promising trends are emerging across these sites.

The Mathematics Studio Program includes several components: seminars on pedagogy and leadership for teachers and administrators, one-to-one leadership coaching for principals and other school leaders, math content courses for teachers, and the use of "live" mathematics classrooms as studio context for rehearsing specific teaching practices designed to foster student engagement in high cognitive mathematical tasks and practices. While the seminars and courses address current and relevant content, they are more traditionally-structured learning experiences. The most innovative aspect, and the heart of the program, is the studio classroom, which serves as a site for multiple layers of learning through "real time" public rehearsals and applications of ideas and practices learned during the seminars and courses. (It helps to think about the term "studio" in the sense of the artist's studio – a site for trying out and refining designs and practices that press on the boundaries of one's current beliefs and ways of working.)

Envision a teacher (the Studio Teacher) and 12-15 colleagues (the Studio Residents) gathered around a table to <u>collaboratively plan for instruction</u> in the Studio Teacher's classroom. The Residents are other teachers of mathematics from the school, the principal, school specialists such as SPED and ELL, and a district office administrator. Residents "do the math" together, anticipate student conceptions and strategies, clarify student learning goals, debate and strengthen the cognitive demand of the mathematical task, and identify and detail specific teaching moves that will engage students in relevant and productive mathematical practices and discourse. They use structured protocols and supporting tools to focus their planning and dialogue.

Next, the Studio Teacher <u>enacts the plan</u> "live" in her classroom, while the Residents observe and record student discourse data using specified data tools that focus their attention on key features of mathematically productive student discourse.

Immediately following the classroom enactment, the group <u>debriefs by examining the discourse data and students' written work, followed by structured inference dialogue</u> about relationships among: the math content; students' mathematical justifications, generalization, and use of relevant CCSSM math practices; the lesson design; and instructional moves. Protocols support reflection and dialogue that always include generalization by all participants regarding next steps for their individual and collective practices. Finally, the day may end with teams of Residents applying their learning and launching their instructional next steps by rehearsing with small groups of students while their colleagues observe.

Throughout the above planning, enactment, and debrief processes, there is <u>a coach who works closely with the Studio Teacher and Residents</u> to press for reflection and support instructional decision-making, to facilitate the group's use of specific tools and protocols, to coach the public rehearsal of specific practices, to make the nuances of selected instructional moves and decisions transparent, and to coach, model, and make transparent the features of highly productive professional dialogue. Initially, this coach is an external consultant – over time, as the structures and protocols become internalized and deprivatization through coached public rehearsals become the norm, local teacher leaders take over studio facilitation.

In schools with more mathematics teachers than can be accommodated together in a studio, one or more additional Resident cohorts participate on another studio day in the same or another studio classroom. Each year there are typically four or five studio cycles in a studio classroom – during each cycle, each cohort of Residents spends a studio day in the same classroom. In addition, there is a half-day of leadership coaching for the principal during each cycle, focusing on coached rehearsals of leadership practices, tools, and structures designed to analyze, support, and accelerate teacher and student learning.

When implementation takes root in a Studio school, as evidenced by student data, the school may become a living "greenhouse" for seeding expansion of the studio model. Cohorts of teachers and administrators from other schools/districts attend the greenhouse studio to develop readiness for launching their own studio work. Pre-service teachers and their supervisors from local universities are Residents in selected greenhouse studios. Teams of administrators form "leadership studios" in the greenhouse school, focusing on planning, enacting/rehearsing, and debriefing specific math leadership strategies. Researchers use the greenhouse studio school as context for a variety of research agendas (e.g., the ecology of the school, mathematics learning and teaching, issues of equity, leadership and organizational change). Whether growing classroom by classroom, school by school, across a K-12 feeder pattern, or district to district, the studio model is attainable and scalable through thoughtful organization and allocation of resources.

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Michael S. Garet

American Institutes for Research

Describe, based on your expertise and knowledge of research, what it would take:

Rather than respond directly, I will summarize a recent study I participated in, on the impact of an intensive mathematics professional development (PD) program (Garet et al, 2011). The study and its conclusions may provide some insight into the task of designing PD to support implementation of the CCSSM. The study examined the impact of a two-year PD program for seventh-grade mathematics teachers, focusing on teachers' knowledge of rational number topics, including specialized mathematics knowledge that may be useful for teaching these topics. The impact of the PD program was assessed by randomly assigning some schools to participate in the PD and some to a "business as usual" control. The PD was implemented in a relatively large sample, in varied settings, using multiple facilitators. In total, the PD was delivered to approximately 100 treatment teachers in 12 districts in the first year of the study, and approximately 50 treatment teachers in 6 districts in the second year.

The PD program was designed to develop teachers' capability to teach positive rational number topics effectively. For each rational number topic area, the PD program emphasized using precise definitions and the properties and rationales underlying common procedures used with rational numbers. In addition, the PD emphasized developing teachers' ability to explain rational number concepts and procedures, identify and address persistent student misconceptions(often by presenting students with problems designed to reveal their thinking), and use representations of rational number concepts in teaching.

Two providers—America's Choice and Pearson Achievement Solutions—were selected through a competitive process to produce and deliver the PD. During each year of the study, the PD included a summer institute, a series of one-day follow-up seminars held during the school year, and in-school coaching visits conducted in association with the seminar days and delivered by the seminar trainers.

The PD program provided to teachers who participated in both years of the study was designed to deliver 114 contact hours (68 hours in the first year and 46 hours in the second). For teachers who entered the study in the second year, the PD provided 58 contact hours, including the 46 hours offered to all teachers and a 12-hour "makeup" institute that provided a short version of the summer institute from the first year. Data were collected from teachers and students in the study schools in fall and spring of the 2007–2008 and 2008–2009 school years, focusing on three main outcomes: teacher knowledge (measured using a test constructed specifically for the study); classroom instruction (measured using classroom observations); and student achievement (measured using a customized, computer-adaptive rational number test constructed for the study by the Northwest Evaluation Association, NWEA). We also observed the fidelity of implementation of the PD, and surveyed treatment and control teachers to gather data on their professional backgrounds, and on the amount and type of PD in mathematics they participated in during the two-year study period.

The data indicate that the PD was delivered as planned. Across the six districts that participated in the study for two years, the average number of hours of institutes, seminars, and coaching delivered was 118 hours, which was 4 hours more than the intended dosage of 114 hours. Treatment group teachers in the six two-year districts attended an average of 77 hours of study PD. Teacher turnover limited the maximum possible PD dosage; treatment teachers attended 89 percent of the PD that occurred during the time they taught in the study schools.

The PD program did not have a statistically significant impact on teacher knowledge or on student achievement in rational numbers at the end of the first or second year. Observations of teachers were conducted in the first year only. The PD program had a statistically significant impact on one measure of instructional practice (the *teacher elicits student thinking scale*), a nearly significant impact on a second (the *teacher uses representations scale*, p = .054), but no significant impact on the third measure of instructional practice used in the study (the *teacher focuses on mathematical reasoning scale*).

Exploratory analyses based on a pooled sample, which combined data from the first and second years of the study to maximize the precision of the estimated effects, suggest that on average, each year of the PD had a statistically significant positive effect on teachers' *specialized knowledge of mathematics content* (SK), one of the two dimensions of teacher knowledge measured by the study. There was no effect on teachers' *common knowledge of mathematics content* (CK), the other dimension of teacher knowledge. Other exploratory analyses suggest that there was no significant differential effect of the PD for teachers who differed in baseline knowledge or prior experience, or for students who differed in baseline achievement. Exploratory analyses suggest that students taught by teachers with higher knowledge scores exhibited significantly higher achievement, after controlling for prior achievement and other student background characteristics.

Describe, in some detail, one idea you have for how professional development can be done at scale:

While one should not generalize too far based on a single study, the PD Mathematics Study results raise questions about the strategies required to deliver effective PD on challenging mathematics content reliably at scale. Although the results indicate that teachers' mathematical knowledge may be associated with student achievement gains, and thus may be a useful focus for PD, the PD tested did not have an effect on teacher knowledge of a magnitude that translated into an impact on student achievement. The results suggest that teachers' SK may have improved with each year of study PD. However, it is unclear whether multiple years of PD would produce larger gains in SK, especially without configuring the PD to take into account teacher mobility. Within a given year, our impact results suggest that, in order to affect achievement outcomes, the PD would have to be more efficient than the PD tested here in improving SK on an annual basis. Finally, while our evidence and evidence from other studies indicates that there is an association between teacher knowledge and student achievement, we do not know the relative importance of SK and CK. The study PD was primarily focused on SK and was not as directly focused on CK. Providing PD that places more direct emphasis on CK is another potential avenue for future study.

While we cannot be sure what features might strengthen the PD we tested, several strategies seem worth exploring:

- Increased accountability for teachers to learn and implement topics in PD (e.g., through the teacher evaluation system)
- Increased opportunities for teacher practice, focused on both content and instructional strategies
- More explicit feedback based on clear standards (including graded work)
- Improved coaching quality (selection and preparation)
- More explicit curriculum for teachers leading from basic to advanced topics and reflecting variation in teacher background
- Tighter links to the curriculum or student assessments
- Changed balance between focus on content and specific instructional strategies
- Explicit programmatic features to cope with teacher turnover (40 percent of teachers present at the end of the second year of PD were not present at the start of the first year)

Identify a small number of articles that have influenced your thinking:

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Kennedy, M. (1998). *Form and substance of inservice teacher education* (Research monograph no. 13). Madison, WI: University of Wisconsin-Madison, National Institute for Science Education.

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Siegler, R., Carpenter, T., Fennell, F., Geary, D., Lewis, J., Okamoto, Y., Thompson, L., & Wray, J. (2010). *Developing effective fractions instruction for kindergarten through 8th grade: A practice guide* (NCEE 2010-4039). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

For a more detailed account of the Middle School Mathematics PD study, see:

Garet, M., Wayne, A., Stancavage, F., Taylor, J., Eaton, M., Walters, K., Song, M., Brown, S., Hurlburt, S., Zhu, P., Sepanik, S., and Doolittle, F. (2011). *Middle school mathematics professional development impact study: Findings after the second year of implementation.* (NCEE 2011-4024). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Michael Golden

Educurious Partners

The Need Seen in a New Way: At an education conference last month, Craig Barrett, former CEO of Intel, calculated the probability any US student will have all great mathematics teachers throughout his/her primary and secondary school career. Estimating that 70% of math teachers in each grade in successful districts are great, taking .70 to the 12^{th}, the probability is almost zero that a student will make it through twelve grades without getting a bad math teacher. In many poorer districts, where a lower percentage of math teachers are great, every student is almost guaranteed to get bad math teachers repeatedly. Two bad teachers in a row begin to create an insurmountable gap for students to bridge. One key way to ensure this outcome doesn't occur is to ensure every math teacher is great. Even with properly designed professional development (PD), how can we take such an initiative to scale?

Make Professional Development Meaningful: One huge challenge we face in making PD meaningful is designing and implementing the type of PD of CCSSM that will make mathematics instruction engaging, vital, meaningful, relevant and individualized for each student. Is this the mathematics that is important to know, and what evidence is there that the students are learning it (Moyer-Packenham)? It is the fact that mathematics is relational and understanding it in that way should be the goal of our curriculum and pedagogy as well (Malloy, 2003). Scientific constructivist accounts of learning stress this (Battista), so we must change our systems to focus on these goals.

We must adopt rich, rigorous and ongoing PD that is sustained, intensive, and continuously woven into the everyday fabric of the teaching profession through modeling, coaching, and collaborations (Kleiman, 2007). To do that, each teacher must have the support structure, the self-reflection and the lifelong learning perspective to undertake this work. They must become exposed to concrete classroom examples and experiences on which to ground an inquisitive, respectful and discerning conversation about practice (Wilson, 1996). We must align the structural and systemic elements across the education enterprise to provide these opportunities to all teachers. And, we must ensure pedagogy and practice translates into classrooms across the US filled with critical mathematics.

Showcase model practitioners and develop coaches: While I was Deputy State Superintendent in Pennsylvania, we established a program to celebrate model practice teachers across the Commonwealth. The Keystones program lets school leaders honor teachers in their schools, with selected Keystones given PD and networking opportunities to learn how to take their expertise to even higher levels. The initiative works to establish change agents within the system to lead and mentor their peers. We found success in networking these progressive teachers with each other through technology and empowering them to take on a mentoring and teacher-leader role in their schools. It is also through technology that we are able to open the black box and share these model practices taking place between teachers and students. We must ensure that mathematics "Keystones" are identified across the country, so they establish a repository of videotaped mathematics best practices and shared lesson plans and activities tied to the CCSSM to share with all teachers.

Create an inquiry-based Professional Learning Community that serves as a model for pedagogy: Needless to say, establishing a PLC is ongoing work—constantly evolving and changing as the variety of factors that influence it change. It is through inquiry that teachers at all stages in their PD make problematic their own knowledge and practice, as well as the knowledge and practice of others and thus stand in a different relationship to knowledge (Cochran-Smith and Lytle, 1999). The intellectual and emotional habits of critical reflection and action about one's calling and daily work are the mark of a professional continuously engaged in self-improvement (Goodlad, 1994, as quoted in Fullan, 1994). It will be much less problematic to institute an inquiry-based teaching stance in every classroom once it is part of every teacher's learning stance. These communities can be distance learning ones, too, utilizing social media networking and synchronous/asynchronous interactions.

Overhaul pre-service training: We must establish guidelines for pre-service teacher programs to ensure they are producing graduates prepared to hit the ground running on Day One in school with facility with

[1] I use "people" to refer to the specialists (district- or university- level) and classroom teachers. That said, involving principals and other district administrators could provide some powerful learnings and support systems, too.

CCSSM, data-driven decision making skills, an understanding of universal design and individualized instruction, and the ability to seamlessly integrate technology into instruction to instill 21st century skills in students. Since the role of the teacher in a problem-centered, inquiry-based classroom is different, colleges of education need to model that behavior accordingly. If learners are to have opportunities to explore rich problems within which the mathematics will be confronted, the instructor has to…(a) engage learners in problems in context, (b) push learners' thinking while their exploration is proceeding, (c) help learners to make the mathematics more explicit during group interaction and whole class synthesis and summary, and (d) use and respond to the diversity of the classroom to create an environment in which all learners feel empowered to learn mathematics (Lappan, 2000).

Reach the tipping point for fundamental change in each school: Burn out, ostracism, and disillusionment occur when individual teachers try to undertake this work without the support and involvement of the school population in general. We must accurately assess the existing culture, pedagogies, need and readiness, internal principal and teacher leadership, and their assumptions and suitability to this transformation. These readiness data will not only inform the rollout in each school, but they will serve as baseline data with which to evaluate and monitor improvement over time in that school. In addition, these data will inform our work across the variation in current school contexts as we develop different models of implementation for these diverse environments, common in the strength of their PLCs. District leadership and school board directors also need to be willing to support the work over time, since none of these transformations are instantaneous.

Engage student voices: Without input from digital natives, teaching and learning will never progress from full-frontal to co-constructed. Ensuring content is rigorous and relevant, with students taking responsibility for their learning, requires engagement by the students. It is especially crucial in mathematics, given the problematic social acceptance to declare, "I am just not good at math and it is not relevant to me or my life." Conversations on instructional, administrative and governance issues will benefit from their involvement. Underlying this inclusion of student voices in decisions relevant to their education presupposes a "difference" model for student learning as opposed to a "deficit" model. It bears upon the culture and the functioning of the school. With such an approach, all will benefit.

As explained by Paulo Freire, reading the word is dependent on reading the world. If we truly believe that mathematics learning is "reading the world through mathematics," all students must be constantly exposed to a multimedia-integrated pedagogy and inquiry-based learning that supports their learning of relationships and patterns, engages and motivates them, and provides to them a fundamental and enduring understanding of mathematics for lifelong learning. Therefore, every teacher must have the skills, knowledge and disposition to guide his/her students in that direction. Together over these two days, we must establish a CCSSM-PD implementation plan to make that a reality.

Lynn Goldsmith

Education Development Center, Inc.

1. What Would it Take to Design Professional Development?

I'm surprised to find myself writing about *designing* professional development (PD) systems, since most of my work involves the other end of the process—investigating what teachers take up from PD. But, working backwards from teacher outcomes, I started thinking about some basic design issues/decisions that seem worthwhile to reflect upon.

Selecting a focus for PD. Personal mathematics knowledge and habits of mind, beliefs about the nature of mathematics, epistemological viewpoints, dispositions to attend to students' thinking, aspects of instructional practice—these are among the many aspects of teachers' knowledge and skill that could profitably be the focus of PD efforts. Though it might seem obvious, figuring out where to focus PD is important. In some recent work with Helen Doerr and Catherine Lewis in which we've been reviewing the literature on teacher learning (much of which is about PD), we've been struck by the number of PD projects addressing a variety needs, on a variety of fronts, more or less simultaneously. We came to think of these as "kitchen sink" studies because they had so many moving parts it was hard to tell what aspects of teachers' knowledge and practice they *weren't* working on; it was also difficult to understand what parts of the intervention were influencing teachers' learning and to identify possible mechanisms by which the PD was having an effect. I think that having a clear, sharp focus when designing PD can help target specific learning goals for teachers, making it easier for teachers to have a sense of the PD terrain and for developers and researchers to know what to look for in terms of assessing implementation fidelity and teacher outcomes. A clear focus can also make it easier to think about the broader arc of PD over the long term, identifying a focus for the current PD and thinking about how it might connect to subsequent PD needs.

Learning trajectories/progressions. Learning progressions are kind of like educational triptiks that map a route toward developing expertise. For planning PD that focuses on helping teachers understand the development of students' mathematical understanding, for example, design efforts would profitably include attention to known learning progressions for content areas emphasized in CCSSM; for areas that do not currently have well-articulated learning progressions, PD design might include working with teachers try to develop their own (Jim Popham just organized an AERA symposium on this issue). Additionally, PD design would be strengthened were it to address *teachers'* learning trajectories—at present, this is an area which is largely under-researched, but which could have significant impact on PD design.

Selecting a PD model. I think it's worth distinguishing between "highly specified" and "emergent" models of PD. Highly specified PD is essentially the teacher version of classroom curriculum—developers create materials that articulate a series of structured experiences which are intended to be (bought and) used in different sites more or less as is (e.g., Driscoll et al.'s *Algebraic and Geometric thinking toolkits*, Schifter et al.'s DMI series, Seago et al.'s *Learning to teach linear functions* and Smith et al.'s *Using mathematics cases to transform mathematics teaching materials*). In contrast, emergent PD is more grounded in the local context of a given group of teachers; decisions about PD focus and activities are, in general, more "just in time" and contingent on a given group's needs and interests (e.g., lesson study, video clubs [c.f. Sherin and colleagues], and PD based on the Problem Solving Cycle [Borko et al.]) The "portable" parts of emergent PD programs are the structures and principles that support the PD goals and inform decision-making as the work unfolds at individual sites. Highly specified and emergent models of PD are likely to afford somewhat different kinds of learning opportunities for teachers, and also to lead to different ways of thinking about what constitutes "fidelity of implementation" and what it means to achieve scale.

"Ongoing" PD. While pretty much every accounting of best practices for PD includes a statement that it must be ongoing, I don't think we've necessarily unpacked what "ongoing" means. For example, while we tend to think that more is better, Heck et al. reported that for some of their outcome measures, the effect of PD attenuated after a certain (relatively large) number of hours.

In fact, the description of PD as ongoing seems to have been a handy way, a decade or more ago, of distinguishing between the common, "one-off" workshop and PD experiences that are more intensive and sustained over time. I'm not sure we've moved very far beyond this distinction to critically explore how the duration of PD contributes to promoting teachers' professional growth. (Nor is it clear to me that we have a lot of data with which to undertake such an exploration. Less than 15 percent of the of the 200+ articles that Helen, Catherine, and I reviewed, for example, reported on PD that was more than 12 months' duration.)

Cognitive/developmental theories point to periods of disequilibration and periods of consolidation of new understanding/skill; is it possible, for example, that there are times that teachers might benefit from a rest from active PD involvement? Or do we rather want to think about "ongoing PD" in terms of a culture of continuous professional investigation that's more in the spirit (if not the form) of Japanese lesson study in that inquiry into practice is considered an integral part of teachers' professional lives and may well take different forms at different points in time? If so, perhaps we think of PD design in terms of phases that involve some combination of learning opportunities drawing on outside expertise (e.g., emergent or highly specified PD curricula, coaching) and other opportunities that involve developing generative and self-sustaining explorations with colleagues (e.g., lesson study or some kind of PLCs). I also suspect that we need to better understand possible systemic barriers to promoting ongoing PD.

PD Facilitation. While the field has paid a lot of attention to teachers' facilitation of classroom learning, we know less about the challenges involved in facilitating teachers' professional learning. As we seek to go to scale with PD programs, the need for skilled facilitators becomes a bigger and bigger issue, and attention to facilitation demands (and provisions for facilitator support/training) should be a consideration in PD design.

For whom the PD tolls. The vast majority of the PD I've read about, and virtually all of the PD I've been involved with, has focused on volunteers thereby generally resulting in a receptive and cooperative collection of participants. PD design must undoubtedly take into account ways to motivate participants and address other affective issues; how does the design burden change when *all* the teachers in a building/district are obligated to participate?

2. Thoughts about Scale

I have cleverly left myself very little space to write much about this question, mostly because I don't really think about scale all that much and don't have any detailed plans to share. Given that the context for our thoughts is considerations about PD that will help teachers realize CCSSM, and that there seems to be a fair amount of state buy-in, one positive note with regard to achieving scale is that PD tied to CCSSM is likely be relevant across a variety of states and settings and therefore has the potential to be wide-reaching. Beyond that, I can imagine some challenges involved in bringing PD to scale. For example:

- Providing adequate training/support for facilitators
- Being able to effect both volunteer and non-volunteer participants
- Using a variety of media to reach large numbers of teachers (face-to-face PD, online, some version of PLCs).

(Selected) Influential Resources

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Three major ideas influence my perspective on what the math education community needs to be considering as they begin to articulate research ideas that could support the implementation of professional development (PD) needed for making the CCSSM a reality for K-12 teachers. The three ideas include: using existing starting points, defining the needs and work of various stakeholders to support the implementation of the CCSSM, and identifying support mechanisms needed to translate PD into classroom practice. These ideas are based on the assumptions that the field of math education has made some progress in the last decade and there is no need to start over, implementation of ideas about teaching, learning, and curricular content is a systemic matter, and the question of how to translate learning within PD to classroom practice as well as how to assess in meaningful ways the resulting impact on teaching and students' success remain major problems whose ultimate solutions are found within the daily practices of classroom teachers.

Starting Points

Creating, sustaining, and assessing PD systems for making the CCSSM a reality is an enormous undertaking but not something that requires any of us to start with a blank slate. As the PIs of this meeting indicate, the National Staff Development Council (2009) provides us with four research-based principles for PD is certainly a starting point. Another starting point is found in the existing Math Science Institute Partnership (MSP) grant programs funded by the National Science Foundation for nearly a decade (http://www.nsf.gov/funding/ pgm_summ.jsp?pims_id=5756). Within these projects, one can find interesting designs of PD aimed at improving the capacities of K-12 mathematics teachers. One can also find research designs embedded within these projects aimed at studying the impact of PD on student success. You can find more information about the funded projects themselves, as well as findings from the research they are doing, at http://hub.mspnet.org/. Further information about the work and progress of some of these NSF projects may be gleaned by examining the strengths and limitations of these projects found in articles in the *Peabody Journal of Education* (2008, Volume 83, Number 4) and *Journal of Educational Research and Policy Studies* (2006, Volume 6, Number 2). Further understanding of how these NSF-funded projects see their professional development and research agendas relating to student success can be found in the abstracts that were written and submitted by these projects for the Learning Network Conference in January 2011, attended by PIs of these various grants. These abstracts can be found on http://hub.mspnet.org/index.cfm/msp_conf_2011 . As an organizer for this conference who helped PIs revise their abstracts, I noticed the depth of the challenge for most projects of continuously keeping in the forefront of all phases of both PD and research the ultimate goal and responsibility to have one's own work as a teacher educator or research held accountable to the need to increase all students' success.

One feature of these MSP projects is the need for STEM faculty to develop partnerships with mathematics education faculty. Such partnerships seem imperative to the work of implementing the CCSSM in that the demands for mathematical content knowledge for teaching demands are high, and helping the content of what teachers need really requires disciplinary contributions from mathematicians who care deeply about teaching and interdisciplinary partnerships between mathematicians and mathematics educators. See *Notices of the American Mathematical Society* (Volume 58, Number 3). Another text worth noting is Hora and Millar (2010) book, *A Guide to Building Partnerships*.

Defining and Supporting Needs of Stakeholders

It will not be adequate to just replicate existing programs of PD and research as a means of supporting the implementation of the CCSSM. One needs to think carefully and deeply about how to translate the strengths of the content and design of existing programs of teacher education and research to the particular context in which one is working. One also needs to consider the needs, knowledge, and past experiences of current stakeholders, including classroom teachers, building administrators, district administrators, district curriculum leaders, state level curriculum leaders, and parents. Where are each of these stakeholders in relationship to the mathematical content and practices represented within the CCSSM? Where are the stakeholders in terms of their relationship to reform-minded images of mathematics teaching and learning?

While the goal is to acquire national standards, and in doing so acquire consistency and continuity across the USA in terms of K-12 mathematics teaching and learning, how these standards are learned and translated into real classroom practice by stakeholders is a localized problem. It is important that those who lead professional development begin with an assessment of current individual stakeholders. Comparable to stating that the ultimate product of our efforts to implement the CCSSM should be increasing student success, the ultimate translators of these standards into practice will be classroom teachers. Teachers are street-level bureaucrats (Lipsky, 1980/2010), interpreting and enacting their own understanding of the reforms. Hence, just as all of our efforts must be focused on achieving the end product of student success, the process of supporting stakeholders in the process must all be done in ways that ultimately focus on and support teachers as they work daily with K-12 students to translate policy into practice and, in turn, increase all students' success.

Finally, I think we need to be asking several questions regarding the nature of the work and the support needed for stakeholders. What is the nature of the work each of the stakeholders need to do or need to learn how to do to ultimately support individual teachers in enacting the CCSSM in K-12 classrooms? What kinds of support do they need, in the short and the long run, to do what they need to be doing or need to learn to do? How can we help stakeholders see the work they must do and put in place processes to support their learning?

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What Might my Design Involve?

My background involves working in professional development school (PDS) settings as a graduate student and facilitating action research and lesson study cycles (AR/LS) as a faculty member. Both of these types of professional development (PD) take as a starting point the assumptions expressed in the National Staff Development Council (2009) report described in the invitation to this conference. In particular, they advocate for long-term, intensive relationships and generating evidence of teacher and student learning. Yet, these models of PD are also built on some additional assumptions that I think are imperative to teachers learning about and enacting statements put forth in written documents such as the CCSSM. In the same way that Remillard describes the ways in which teachers "read" curriculum materials, I believe that the reading of documents like the CCSSM requires reading, interpreting, and making sense from one's own knowledge, beliefs, identity, etc. I also believe that teachers and other specialists (e.g., math specialists or university folks) who are involved in the kind of PD advocated by PDSs and AR/LS must be seen as bringing valuable knowledge bases to the table and that these groups must be built on mutual respect and genuine relationships—that "others" don't know *more* than teachers, rather all knowledge bases are valuable and important in this work toward creating better teaching and learning.

Thus, I see partnerships as particularly important—these partnerships would bring mathematics specialists or university faculty into long-term collaborative relationships with teachers and administrators with the dual goals of: a) making sense of the document and b) figuring out how to enact the ideas put forth in the document in ways that best serve students in a particular context. Doing this kind of work would require time to read, make sense of, interpret, and discuss the document and relevant literature that could help to unpack many of the ideas. For example, there may be readings on particular content ideas that could provide a context in which people[1] could work on mathematics together and reflect on misconceptions students have related to those ideas or they might read some about the mathematics register in order to better understand things like "efficient" language use, the relationship between language and symbols, and "articulate arguments." In tandem with these reading groups, a context would be required in which teachers could try out and investigate the ideas in their classrooms, reflect on those enactments, talk with others about what is going well and what is not, support each other in doing things better, etc. This is when the action research and/or lesson study would be part of the PD process.

These kinds of relationships with K-12 schools and district- or university- level people could not only help everyone learn more about teaching and learning mathematics, it can also help work toward the professionalization of teaching and teachers. As Cochran-Smith and Lytle (1993) remind us, collaborating *with* teachers versus conducting research *on* or *about* teachers has the potential to transform knowledge about teaching, to redefine PD and teacher learning, and to change the ways in which teachers and students relate to each other, toward more democratic purposes. A more thorough description of a model for PD that I designed for my CAREER grant that is similar to this work can be found in Herbel-Eisenmann (2009; 2010).

What Would it Take to Implement Such Professional Development?

I am not able to describe all of this in such a short memo, but teachers would need to be supported in many ways to do this kind of intensive work. For example, I could see the **specialists** as serving in more logistical roles, such as being the person to organize and schedule meetings, find resources to help teachers grapple with issues that come into play as they make sense of and learn to enact the content and practices put forth in the CCSSM, and help to order equipment or videotape if needed. Additionally, they could serve the role of questioner, asking questions to help teachers become aware of their beliefs and values, to help teachers articulate their goals, to discuss the relationship between claims-evidence, and to serve as an advocate for the teachers as they do this difficult work. **Administrators** would need to be on board, to support and advocate for these professional learnings. This might involve hiring practices that include these aspects of professionalism in their job postings and interviews, creative scheduling options that open up mutual time for teachers to work together and meet during the school day, town forums in which s/he explain what they are doing and why they are doing it, participation in the study groups, taking on the role of "instructional leader and mentor" instead of evaluator, etc.

One Idea for How Professional Development Can be Done at Scale

Although I'm less familiar with the literature on the structures and policies in Asian countries that do this kind of intensive work, I would think this literature might be a good resource for helping us think about what might need to be in place for these things to happen. The work of people like Dan Chazan could serve as important examples, too.

I recently interviewed Lynn Paine (a scholar of Chinese education), for example, and she reported quite different views on how to help schools and teachers enact policy and teaching practices (see Choppin, Wagner, & Herbel-Eisenmann, in press). She noted in her interview that a primary goal of local educational policy in China is to provide resources that help teachers develop the capacity to teach the mandated curriculum in ways that provide improved opportunities for students to learn mathematics:

> [The policy] was saying something is getting in the way of these kids learning and these teachers being able to support their learning, and let's figure out policies that might support the conditions that could or create the conditions that could support them … Now the goal is clearly equity, … concern that the larger portion of kids weren't achieving at the level that people might hope, but the problem wasn't the kids, and the problem wasn't even entirely the teachers, but it was a capacity issue where there needs to be learning, so there was a policy geared towards learning, which feels different from a policy geared towards measuring outcomes. What got produced was different [in many contexts] so in some cases it meant teachers were seconded from school A to school B to spend time teaching in a very different school [for a period of time]… or a principal would be assigned to become the principal of two schools or to leave the school and work at another school and it worked out differently in different places in [Shanghai] but that seemed like a really novel approach … but the focus of the policy was very different from [the way we focus policy in the U.S.]

In her research, Paine describes how Chinese teachers form learning groups (similar to lesson study) around "learning how to think about an important topic and content and then try to understand what's hard for kids about this content, [which they do] by actually interviewing kids who've studied that topic in the past." They then use this information as data to improve the teaching of those topics. The overarching goal of these learning groups is to figure out how to best teach every child, particularly with respect to content areas in which many students struggle. Additionally, she explained how the teachers worked together to develop formative assessments that could be given at different points in time, drawing on this data to better understand what students were learning and using that information to inform their instruction. In China the corrective to inequities involves providing schools and teachers autonomy to improve instruction for all students, rather than the punitive systems that are more often put in place in the U.S. Policy in China involved a structure that mandated that the voices of students and of teachers were valued and instrumental.

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*I mainly include work related to collaborations and leadership, although I also draw on work related to case-based learning (e.g., Peg Smith and colleagues' work) and learning in video clubs (e.g., Miriam Sherin and colleagues' work).

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In writing our Briefs, we were encouraged to focus on our own perspective and expertise. I do not know much of the contents of the new CCSSM, nor do I have much expertise in mathematics professional development (PD) – what comprises good PD, nor how to best design PD, nor how to scale it up. Hence, here I will focus on my own research and knowledge of research that may be relevant to these issues.

Research on Induction for Beginning Teachers

If we view PD writ large and in the general sense of any kind of development along the professional continuum from a teacher's recruitment to their retirement, then induction for beginning teachers could be considered a subset of PD – a form of PD that is tailored to beginning teachers.

With a colleague, I recently completed a review of extant empirical studies that have sought to evaluate the impact of induction and mentoring programs for beginning teachers (Ingersoll & Strong 2011). Our review found and critically examined 15 empirical studies, conducted since the mid 1980s. Most of the studies reviewed provided empirical support for the claim that support and assistance for beginning teachers have a positive impact on different outcomes: teacher commitment and retention, teacher classroom instructional practices, and student achievement. Of the studies on commitment and retention, most showed that beginning teachers who participated in some kind of induction had higher job satisfaction, commitment, or retention. For classroom instructional practices, the majority of studies reviewed showed that beginning teachers who participated in some kind of induction performed better at various aspects of teaching, such as keeping students on task, developing workable lesson plans, using effective student questioning practices, adjusting classroom activities to meet students' interests, maintaining a positive classroom atmosphere, and demonstrating successful classroom management. For student achievement, almost all of the studies showed that students of beginning teachers who participated in some kind of induction had higher scores, or gains, on academic achievement tests.

Several findings from this review may be useful to the design of PD and the CCSSM. First, both theory and some of the evidence suggest that the quantity of induction is important. That is, programs that are more comprehensive, or longer, or include more depth of support have better results. In particular, this was a finding of the most ambitious study yet done on the impact of induction on beginning teachers—a randomized controlled trial study conducted by Mathematica Policy Research. Their study found that for student achievement, there were significant and positive effects of teachers having received comprehensive induction, but only after two years of participation. In other words, the study found that it took two years of receiving comprehensive induction before the scores of students taught by teachers participating in induction were significantly better than those of the teachers not receiving comprehensive induction. The implication is that a small amount of PD may not have long-term benefits and there may be a minimal "tipping point" or threshold, below which PD is of little value. It is, however, unclear what is the optimum program length and intensity for such programs, beyond which additional time invested diminishes in value.

Second, some of the research suggests that context matters, and that induction's efficacy, may depend on the school setting. Existing descriptive research suggests that the content, duration and costs of induction programs vary greatly among states, school districts and schools. And, some of the evaluative research suggests that induction programs may need to be tailored to settings to be effective. For instance, effective induction in urban, low-income, public schools may necessarily differ from effective induction in suburban, affluent schools. The implication is that a one-size-fits-all model may not work for designing system-wide PD for CCSSM.

The Effects of PD on Teacher Turnover

In a recent study using national survey data, we examined the magnitude, destinations, and determinants of the turnover of mathematics and science teachers from public schools (Ingersoll & May 2010). Among a number of key organizational characteristics and conditions of schools, we looked at whether PD activities focused on student discipline and classroom management, and PD activities focused on the teacher's subject-area content, had any relationship to math teacher turnover. For the measures of PD activities, we utilized two survey items on participation in, and the usefulness of, activities focused on student discipline and classroom management, and also activities on subject-area content, as reported by teachers.

After controlling for the background characteristics of teachers and schools, our statistical analysis found that math teachers who participated in, and found useful, PD that focused on student discipline and classroom management, had significantly lower likelihood of turnover. The relationship was large. A 1-unit increase in the utility of PD focused on student discipline was associated with a 39 percent reduction in the odds of turnover for mathematics teachers. We also found significant associations for the utility of PD focused on subject content. Math teachers who participated in and found useful content-focused PD had a 27 percent lower odds of turnover.

The implication is that PD focused on both student discipline/classroom management, and that focused on the content of the subjects taught are useful for math teachers' retention.

In this same analysis and also another earlier study (Ingersoll 2003), we examined the impact on turnover of faculty decision-making influence over a number of key issues in schools, including determining the content of in-service PD programs. We consistently found that schools with higher levels of school-wide faculty decision-making influence had lower levels of turnover, for both math and other teachers. This was one of the stronger relationships we found. For instance a 1-unit increase in reported faculty influence between schools (on a 4-unit scale) was associated with a 23 percent decrease in the odds of a teacher departing. While our composite measure of faculty influence included influence over in-service decisions, we did not break out and separately examine the impact of faculty decision-making influence over in-service professional development. Notwithstanding this limitation, the implication of these findings is that it is important to include teachers themselves in the creation and implementation of PD. That is, PD should not be something done to or for teachers by administrators or outside experts, but something one with or even by them.

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Describe what would it take to design, implement, or assess quality of mathematics professional development that would support the implementation of the CCSSM content and practices.

This is a big question. If the CCSSM are to guide mathematics instruction better than the NCTM standards have, then I think one fundamental issue is how professional development (PD) is designed to engage teachers, departments, buildings, districts, and states in making sense of them. One could read the CCSSM, despite its attempt to identify a pared down set of big ideas, as a new set of lists of what to cover in the school curriculum at each grade level. Lists tend to limit teachers' and schools' opportunities to understand how central ideas are connected.

I'm also thinking about how PD tied to the CCSSM could engage teachers and instructional leaders to build teaching practices and use curricular resources to meet the learning objectives. We have lots of examples of high-quality PD that is done in small pockets all across the country. We need to articulate what effective PD models and practice-based/job-embedded designs are within schools as organizations that enable collective inquiry into practice. Collectively, teachers need to be focused on how to build classroom, school, and district cultures where teaching is (a) responsive to students' current level of understanding; (b) advance students' competencies and (c) cultivates students' productive dispositions towards learning mathematics. Such designs and models of PD have to be coupled with designs for instructional leadership and networking with more expert others and methods to build the relational practices that are needed if teachers are to learn generatively from their work together.

Describe one idea you have for how professional development can be done at scale:

I'm influenced by Cynthia Coburn's work on scale and considering how scaling up isn't just about numbers. She identifies other facets of scale that have to be attended to: depth, sustainability, spread, shift in reform ownership. Some of my musings here are based on working to engage more teachers and instructional leaders in a common conversation, while attending to the idea that PD has to reach the classroom level. I'm thinking about both national and state leadership in developing PD resources. I'm struck in my local work how much school districts and schools reinvent the wheel, spending hours upon hours creating alignment documents, standards for teaching performance, that end up limiting how much time precious district resources can be spent actually supporting teachers and instructional leaders. One drawback to most standards documents, I conjecture, is that the vast majority of teachers do not fully engage them.

Leading teacher educators could design several day- or week-long institutes that can be led at major regional institutes. These institutes could have different foci. One could be an introduction to the CCSSM. Others could focus on particular domains or particular practices. States or regions could identify higher education, K-12 institutions, or other R&D institutions that could sponsor regional or local institutes using these materials. These institutes would occur regularly (e.g., every summer), focusing on a different strand within the common core and would enable new teachers to engage with what the CCSSM are fundamentally about. The institutes could also be coupled with regional meetings of major practitioner conferences. How common is it for teachers nation-wide or state-wide to have the opportunity to regularly revisit or further their understanding in a commonly-designed PD institute? I'm thinking about trying to solve the problem of having workshops that are ephemeral, but instead creating some structure that can be repeated regularly in a way that enables the continual engagement with various aspects of CCSSM. I have heard others suggest, and I could see the merits, of starting engagement with the CCSSM by helping teachers understand the meaning of the practices.

It's possible for national teacher education leaders to develop prototype institutes so local professional educators are not re-inventing the wheels. Existing, commercially available PD materials could be leveraged to design institutes to help teachers make sense of the key ideas. For example, bundle together a collection from the algebra materials published through CGI, DMI, YMW, and Stein and Smith. Pull out a set of key cases that explicate what a particular domain and practice in the CCSSM mean. I think that's one of the strengths of the proliferation of commercially available PD materials because they have rich cases for engaging mathematical content and practices, as well as teaching practices. The advantage of drawing on this growing set of materials (and I realize we have more materials available in some domains than others) is that it also introduces teachers and instructional leaders to common resources for PD. I have found that many districts, while they try to find funding for coaches or for other types of instructional leaders, are not very informed about the resources that are available to organize mathematics PD. I have also found in our work studying leaders that commercially available PD materials provide good support through their facilitation materials to help leaders provide a common experience.

I know that change in classroom practice is going to take a lot more than sending teachers to institutes regularly. But we lack in the US the ability to have common collective experiences for teachers. This void feeds a cellular, idiosyncratic approach to teaching practice. One challenge we could take on is developing models of practice-based PD so that participation in these institutes could include or be followed up with ways of directly observing and engaging with students. There's lots of nuance and design and development work that remains. We're just in our infancy of trying to figure out how to work with teachers directly on practice. But there are models popping up around the country both in residency programs and in teacher education programs that we could learn from. Taking this on might address the issues of depth and reform ownership that Coburn writes about.

My ideas suggest finding ways of helping teachers engage the document at more than a superficial level and have regular opportunities to focus on different facets of it. It seems to me that we need some common ways of getting teachers inside these documents, rather than having the CCSSM just take up space on a bookshelf somewhere.

We also need better networks and opportunities to build capacity in instructional leaders. Travel of ideas requires people development and leadership development in particular. I'm convinced by Paul Cobb and colleagues, recent studies of leadership coherence and stability in districts organized to support mathematics learning that we have to have engines for creating strong instructional leaders that understand the importance of designing and enacting professional development designs that make sense in local contexts but that also achieve depth, spread, sustainability, and ownership.

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Part 1: What is the Professional Development Problem?

I think that, before outlining a design, we need to articulate what the purpose should be. That is, what is the teacher-learning problem is that we have to solve? The professional development (PD) design should follow from that. We cannot devise solid PD if we don't know what we are trying to teach or what makes that difficult to learn. Below I list some of the problems of teacher learning that I think a PD program should address.

1. The problem of prior learning.

The first problem we have to address is the fact that teachers already know a lot. If we are not working with novices, then we are working with teachers who have already solved many of the problems of teaching. What that means, however, is that a central learning challenge is *unlearning* some of these solutions.

Analysts often talk about unlearning as if it is nothing more than breaking a bad habit, but these prior practices are more than habits: they are established solutions to classroom problems. The practice of suppressing all conversation in the classroom is more than a habit; it is also useful because it helps keep kids on task. We can't simply tell teachers to stop doing that unless we offer them an alternative way of solving the problem they are trying to solve. And we would be dishonest if we claim we have found a way to run more active classrooms, with more discussions or cooperative groups or hands-on activities, and also prevent off-task conversation. The Law of Classrooms tells us that the greater the on-task noise, the greater the off-task noise. They go together.

So a first principle for any PD is that we cannot offer new techniques, or persuade teachers to alter the techniques they are already using, unless we also offer them an alternative way of solving the problems their prior techniques solved for them. And since the problem most teaching practices aim to solve has to do with managing or suppressing students, then the PD has to address that issue even if it's ultimate purpose is to foster better treatment of content.

2. The problem of overcoming habits and routines.

The second problem we have to solve is that most of what teachers have learned, and most of the solutions they have devised, has been codified into habits and routines that can be maintained without thought. That means they aren't even aware that they are doing these things any more. Think of how people manage to stop smoking or to change their diet. It is one thing to make the vow, another to solve the behavioral problem in all the different specific situations where smoking or eating behaviors are habituated.

People are successful at changing habits only when they are strongly committed and when they think strategically about how to make the myriad of small changes that are needed to create the large change. In the case of smoking, people are willing to go through the change because they are persuaded that this is a habit that must be changed. Can we ever persuade teachers that the habits we want them to change are really that serious?

This is more than a matter of having a coach come by occasionally and comment on their work, or having a coach demonstrate different approaches. It cannot happen unless the teacher herself takes ownership of the change process. Changing habits requires a level of self-consciousness about one's practice that is difficult to sustain over time. It requires motivated, attentive self-regulation. It is not clear how PD can motivate such self-conscious attention in teachers.

3. The problem of short-term solutions vs. long-term solutions.

The third problem we have is that many of the solutions teachers have developed are short-term solutions, not long-term solutions. That is, their solutions have an immediate impact on the problem, even though they may not be useful in the long run. For example, a short-term solution to a student talking out of turn would be to publicly scold him, and perhaps punish him by taking away recess privileges or something.

A long-term solution to this problem would be to teach the student to take personal responsibility for his own behavior and to develop his capacity for self-regulation. This is much harder to do. It means finding ways foster a feeling of responsibility toward the larger community, finding ways to foster a feeling of efficacy, and at the same time tolerating a lot of off-task nonsense while you're working on this longer-term goal.

We tend to glibly tell teachers that, when they offer more interesting content, their management problems will go away. This is simply not the case. Management problems are always there.

4. The problem of language.

The fourth problem I want to mention is a problem that lies within professional developers, not within teachers themselves. We have a terrible problem with language. We cannot talk about teaching with any precision at all. We use ambiguous terms like engagement, self-regulation, higher-order thinking, schemata, and worthwhile content, but these terms are rarely linked to specific observable things. So teachers may leave a PD committed to some concept like problem solving, but may understand that term quite differently from what the PD faculty intended it to mean.

On the flip side, the meaning of any given observed event is also ambiguous. A teacher leaning over a student's desk could be an indication of helpfulness, intimidation, or a sexually inappropriate advance. We use language that refers to underlying meanings, but we can't be precise about the any specific actions that are certain to represent those underlying meanings.

Part II: Possible PD Design Solutions

What we need are design principles that acknowledge the nature of the learning that must occur within the PD. We have to confront the reasons why teachers teach as they currently do, and find ways to help them overcome the barriers they perceive to changing their practice. Here are some design principles I propose.

1. The PD provider must be a practicing teacher who has demonstrated an ability to teach mathematics to standards.

The argument here is that if the PD provider is also a practicing teacher, s/he will have, by definition, found solutions to all the problems teachers have to solve, not just the problem of teaching the standards. Furthermore, the fact that PD providers are currently practicing teachers means that they understand the pressures and anxieties practicing teachers face in their daily work. In other words, they know their audience and their audience's goals.

2. The PD provider must demonstrate an ability to articulate the rationale underlying his or her own practices.

The argument here is that it is one thing to be able to teach, but quite another to be able to explain why one is teaching in a particular way, because so much of teaching consists of automated behavior. Thus the PD provider must be not only able to teach the standards and to teach well, but also be able to talk explicitly about why s/he is doing it in this particular way.

3. The PD itself should rely heavily on videotapes of lessons which can be analyzed and critiqued by participants.

This third principle is designed to address the problem of imprecise language. It is important for teachers to see examples of different concepts, but it is equally important that they have time to critique these examples and to ferret out how the full range of teaching problems have been dealt with in these examples, rather than focusing just on how the example illustrates content representation.

4. Individual PD providers should be part of a national network and have opportunities to meet with one another and discuss the problems of PD.

The argument here is that, just as teachers often benefit from discussing problems in their own practice, so too can professional developers. Such meetings provide peer encouragement, reinforce organizational goals, keep members on track and promote continuing self-examination of one's own practice.

Part III: How We Might Set Up Such a System

To find teachers for such a network, I propose beginning with National Board Certified Teachers. These teachers have already been vetted for the quality of their practice, for their ability to reason about practice, and for their ability to articulate a rationale for their practices.

I would not presume, however, that all such teachers are automatically able to demonstrate mathematics instruction that meets new standards. Rather, I argue that these teachers provide a useful pool from which to develop such a community. Some initial mechanism will be needed to admit them to membership in this community.

For the national network, I am envisioning something like the National Writing Project, a loose network of teachers of writing, which has a system for assigning people as simply members vs. members with some level of status. There are tasks teachers can do to raise their status within the organization.
So the proposal would be to start with board certified teachers in mathematics, engage them with the new standards, identify those who seem to be successful with the standards, and organize them into a national association of mathematics teachers who are authorized to help other teachers learn to teach these standards.

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Designing Professional Development to Support the Implementation of the CCSSM

To support the implementation of the CCSSM, professional development (PD) programs are needed that support teachers' understanding and use of the Standards for Mathematics Practices (i.e., pedagogical content knowledge), help them understand the nature and intent of the content standards and the influence of those standards on student expectations in subsequent grades (i.e., learning trajectories), enhance their conceptual understanding of the subject matter so that they can support students' learning appropriately, and provide strategies for assessing students' understandings.

It will be important for PD design teams to be comprised of, or operate in consultation with, individuals with appropriate expertise (i.e., content, pedagogy, assessment, and school context and diversity) to sensitize the group to issues that must be addressed as the curriculum is being developed. In particular, I believe it will be important to include mathematicians as members of the PD design teams, and to the extent possible, implementation teams. I say this with a clear understanding of the complexities associated with such collaborative efforts. However, such collaborations, if done successfully, have the potential to influence not only the mathematical understandings and classroom practices of K-12 teachers, but can also influence the mathematical education of teachers at the postsecondary level. It is important to note that all individuals who engage in such efforts might need some orientation to prepare them to work with others from different fields. Although mathematicians and educators share many common understandings, there are differences (i.e., vocabulary taken-as-shared, schooling experiences, knowledge of school context and teacher needs, knowledge of subject matter) that will need to be negotiated.

The PD designers will need to consider many things that include: the audiences to be served (i.e., new, veteran, or change-of-career teachers; administrators; teacher leaders); the forms in which the PD will be available (i.e., face-to-face, online, or hybrid); the organizational structure of the curriculum (i.e., individualized discrete modules or purposefully sequenced modules); how the program will be supported (i.e., facilitated, group study, or individual study); and the nature of follow-up activities and other support that will be provided. In addition, PD designers must grapple with what is meant by "fidelity of implementation." Because it is important to address the needs of the local context (i.e., "align with school improvement priorities and goals"), PD designers must consider the various ways in which the designed curriculum might be tailored to meet specific localized needs. This is particularly important given the need to determine the effectiveness of developed programs.

Providing Professional Development at Scale

To support the implementation of the CCSSM at the scale needed to influence practices, it will be important to develop PD programs to serve different audiences and purposes. Initially, PD will needed to provide information about the CCSSM. Then, more intensive PD programs will be needed to influence instructional practice.

Introductory Professional Development to Build Understanding about the CCSSM: Introductory PD programs are needed to help all stakeholders (teachers, administrators, and general public) build common understanding about the nature and intent of the CCSSM and its implications for mathematics teaching and learning. Specifically, the goal is to help stakeholders create a vision for the *Standards for Mathematics Practices* and understand the depth at which the subject matter is expected to be taught, learned, and assessed. This type of PD should help stakeholders create a vision for what is possible and serve as motivation for teachers to engage in additional PD opportunities. Although this PD program provides a context for understanding current expectations, it is not intended to result in changes in practices. Although common information will be provided for all stakeholders, there might be a need to tailor this type of PD for particular audiences (i.e., teacher vs. administrators) to take into consideration their particular areas of responsibility. For example, PD for administrators might focus on decisions and practices that might support or hinder the implementation of the CCSSM.

Intensive Professional Development for Mathematics Leaders (Supervisors, Coaches, & Resource Teachers): Intensive PD should be provided to individuals who will support teachers' implementation of the CCSSM. Because these standards are new to all, assumptions about expertise or skills of those who have previously served as PD providers cannot be assumed. Like teachers, mathematics leaders will need support to make meaning about the CCSSM and understand current expectations. They will need intensive PD opportunities to ensure that they have the knowledge needed to function as "more knowledgeable others" who can support their peers. They may need PD that address mathematics content, what it means to teach content at depth expected, and approaches for supporting teachers as adult learners.

Intensive Professional Development for Teachers of Mathematics: Teachers will need intensive and ongoing PD to prepare them to implement CCSSM effectively. This PD should be targeted with the goals of helping teachers make sense of particular standards by focusing on content and pedagogical content knowledge with the aim of helping teachers teach specific content well. Members of localized professional learning communities should engage in common PD opportunities that is supported by more knowledgeable others as they attempt to make instructional changes. Teachers should be provided opportunities to learn about, implement, and discuss the implementation of particular approaches.

Karen D. King

National Council of Teachers of Mathematics

I think there are key issues intertwined that relate to the design and implementation of professional development (PD) supporting the implementation of the CCSSM content and practice. Because of a variety of local issues, I believe that these design and implementation issues should be primarily thought of at the unit of the school or school district. In particular, the district should consider the needs of their teachers, particularly the content and practices knowledge that teachers have, and their overall implementation strategy for implementing the CCSSM when designing their professional development strategy.

Based on my experience, at all grade levels, there will need to be a specific and continuous focus on teacher learning of the mathematics content and practices specific to the grade levels with which the teachers work. In particular, the teachers will need opportunities to experience the practices in the context of doing mathematics, and reflect on what is specific about those practices that need to be taught to students. Thus, teachers need an extensive enough experience with each of the practices that they can begin to reflect on the practices themselves, and think about the practices as goals for student learning. In short, their experiences with each of the practices needs to be rich, deep, and broad enough that the teachers can reify the practices themselves, not only relate to them as described in the CCSSM document, but have their own understanding of what it means to be engaged in each of the practices.

This type of work is a serious commitment on the part of districts and teachers, and should serve as a base for other PD work that teachers are engaged with. PD providers should design these experiences so that teachers can have sustained engagement around mathematical problems, and opportunities to reflect on the mathematics content and practices. However, from a design perspective, the practices should be the focal point of the designers, and there should be a focus on teachers reflecting on their engagement in the practices. For me, while the mathematics problems should be close to practice for the teachers, this type of work should be implemented outside the normal school time, potentially during the summer breaks.

As a follow-up, I would design the next step to focus on connecting the mathematics content and practices to potential student experiences. In particular, I would focus on planning with an emphasis on task selection and adaptation, classroom-based formative assessment, and managing discussions as key areas for teachers to work on in PD sessions. In particular, I would focus teachers' attention on: the affordances of particular mathematical tasks and their features on addressing central mathematical content and practices; the learning progressions of a series of mathematical tasks to build students' content knowledge and ability to engage in particular practices; and key issues in planning to facilitate these tasks in classrooms including questions to ask to monitor key mathematical ideas and ways to scaffold students' learning in discussions and classroom organization. There are a variety of formats for this type of work including lesson study and curricular analysis that can be set in professional learning communities. I am less concerned about the form of the implementation and more focused on the content. Teachers should have opportunities to discuss the key mathematical ideas that can be gotten at using a particular task, how tasks build, and teachers should use tasks in their classroom to learn how to facilitate their use for students' learning. They should also be given rich and ample opportunities to reflect on the use of these tasks and critical feedback on improvement that focuses on specific teacher moves one might make.

An implementation challenge I see is the lack of sufficiently large numbers of PD providers with the knowledge and skill to support such programs of professional development nationally. PD providers with the knowledge of mathematics content and practices to support teachers' learning, and the knowledge of teaching and learning to support teachers' growth in instructional practices, are rare. Given this rarity, I worry about the notions of going to scale. Currently, too few coaches have the knowledge and skill to facilitate PLCs in their schools. To really go to scale, more certifications for mathematics specialists and coaches should be created, as suggested by AMTE and seen in the state of Virginia.

However, I believe these programs should be extended to secondary. There is an assumption that secondary teachers know mathematics because they have mathematics majors or their equivalent. However, my experience in secondary teacher preparation and PD does not always bear that out, particularly for new teachers. Add to this need for content and practice knowledge, the need to translate this knowledge into teaching practices, and I see a need for much more support for secondary mathematics teachers than currently exists. These teachers need many more opportunities to really dig deeply into the mathematical knowledge they need to teach, and to use this knowledge to rethink their teaching practices in light of their thinking about mathematics content and practices.

To assess these PD efforts, at least three levels need to be address: changes in teachers' knowledge, changes in teachers' instructional practices, and changes in students learning. Based on research in PD, these latter two issues are insufficiently taken up for us to know how much and what type of PD changes teachers' practice in a way that is likely to impact student learning. While teacher knowledge is an intermediate indicator of the impact of PD, without change in instruction, there is little likelihood that students' learning will be impacted if their learning experiences do not change.

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Life LeGeros

Massachusetts Department of Elementary and Secondary Education

Please note: the detailed plan represents internal planning by the Massachusetts Department of Elementary and Secondary Education (ESE). Here we share only the broad activities of the project.

Describe, based on your expertise and knowledge of research, what would it take to design, implement, or assess quality of mathematics professional development that would support the implementation of the CCSSM content and practices:

The increased rigor of the new standards will require a corresponding improvement in teachers' instruction, content knowledge, and professional practice. Policymakers and education leaders are obligated to establish systems of professional development (PD) that provide teachers with opportunities to acquire the skills and knowledge they will need to be effective.

Describe, in some detail, one idea you have for how professional development can be done at scale:

ESE will:

1. Establish an **exemplary menu** of state-sponsored PD courses focused on helping teachers acquire the knowledge and skills needed to implement the new frameworks (especially the Standards for Math Practice), including a quality control process that ensures that instructors are consistently high quality.

2. Strengthen the **strategic enrollment** of teachers of mathematics in PD through increased alignment with district and school needs and improved incentives.

3. Build the capacity of schools and districts to provide **systemic support for teacher development**, involving principals as key instructional leaders who oversee ongoing **job-embedded PD** such as instructional coaching, learning walkthroughs, and professional learning communities (PLCs) that leverage the knowledge gained in course-based PD to continually improve classroom practice.

The table that follows details the current and future course offerings of the exemplary menu suggested above.

Title	Course Description	Grade Levels	ESE owned
PD Courses - Current			
Intel Math	Deepens teachers' content knowledge in the areas of fractions, operations and linear functions, with 10% of the course devoted to pedagogical content knowledge. (6 credits)	K to 8	
Understanding Rational Numbers (online and face-to-face hybrid)	Focuses on fractions, decimals, percents, and ratios. (4 credits)	3 to 8	
Increasing Accessibility to Algebra and Geometry for All Students	Offers foundational math content and pedagogical strategies for general education, inclusion and special education teachers. It strengthens teachers' understanding of concepts and relationships between concepts Algebra and Geometry and the use of accessibility strategies. (3 credits)	5 to 10	
Fractions (online)	Promotes a deeper understanding of fractions for elementary school teachers, both from a conceptual as well as a mechanical perspective. (3 credits)	3 to 6	
Academic Youth Development	Prepares teachers to lead mid-level (B- or C in math) rising algebra students in a summer bridge course that uses research on effective effort to prepare students for success in algebra. (no credits)	8 to 9	
Foundations in Number (online and face-to-face hybrid)	Early childhood mathematics concepts with a focus on number sense. (4 credits)	Pre-K to 3	

Title	Course Description	Grade Levels	ESE owned
Job-embedded PD Support - Current			
Mathematics Learning Communities	This facilitator training supports coaches and teacher leaders to create and sustain Math Learning Communities (MLC) using the free MLC materials developed on behalf of the ESE. (2 credits)	K to 8	X
The Mathematics Coaching Cycle (online)	Mathematics coaches and teacher leaders develop the mathematics content knowledge and consulting skills used to assist teachers in acquiring and deepening specialized knowledge and skills required for teaching. (3 credits)	K to 8	
PD Courses - In Development for Summer 2011			
Universal Design for Learning Mathematics (online)	Focuses on lesson planning for Tier 1 instruction using a Universal Design for Learning approach. (3 credits)	5 to 8	X
Developing Math Practices in Number, Operations and Algebraic Thinking	Focuses on implementing the Standards for Mathematical Practice (as described in the 2011 Curriculum Frameworks for Mathematics) in the Number and Operations and Algebraic Thinking Domains. (3 credits)	K to 5	X
Developing Mathematical Practices in Algebra I	Focuses on how the new Standards for Mathematical Practice found in the new 2011 Massachusetts Curriculum Frameworks for Mathematics can be used to prepare students for Algebra I. Based on the current Developing Algebraic Thinking course. (3 credits)	4 to 10	X
Developing Mathematical Practices in Geometry, Algebra II and Beyond	Focuses on implementing the Standards for Mathematical Practice (as described in the 2011 Curriculum Frameworks for Mathematics) in post-algebra 1 courses. (3 credits)	9 to 12	X
PD Courses - Potentially Developed for Summer 2012			
Math Interventions	Specifically addresses intervention and remediation strategies, particularly useful for Tier 2 and Tier 3 students - including enrichment for students advanced in particular areas. (3 credits)	5 to 8	X
Teaching Algebra I in the Eighth Grade	Specifically addresses the teaching of Algebra I (as described in the new *2011 Massachusetts Curriculum Framework for Mathematics*) in 8th grade for accelerated students. (3 credits)	8	X
Sheltered Instruction in Mathematics for Middle School Teachers	Provides teachers with Category 2 PD directly applicable to the teaching of mathematics. (3 credits)	5 to 8	X
Job-embedded PD Support - Potentially Developed for Summer 2012			
Administrator Workshop: How to Set Up Job-Embedded PD Structures to Support Tiered Instruction	Helps administrators understand the concept of systemic support and the components of effective ongoing job-embedded PD, including learning walkthroughs, PLCs, and math coaching.		X
Observing the Standards for Mathematical Practice	Instructional leaders acquire an understanding of what to look for in classrooms that support student engagement with the Standards for Mathematical Practice and how to establish learning walkthrough processes.		X

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Background information and reflections on 40 years of efforts of the mathematics department of Indiana University to provide professional development for teachers of mathematics (research questions and lessons learned are shown below):

Professional development (PD) for mathematics teachers evolved greatly during the 40 years (1966 – 2006) that I was directly involved in the work. A brief summary of mathematics department PD work during this period follows:

1. 1960-75: These years were dominated by the NSF Summer Institutes (funded after Sputnik) in which teachers of mathematics in grades 9-12 spent eight weeks on campus in the summer and came for four consecutive summers. In a typical summer, three courses were offered for graduate credit and the 75 teachers each took two of three courses designed to provide both breadth and depth to their mathematical content knowledge. After four such summers, the teachers received a Master of Arts in Teaching (MAT) degree from Indiana University. The courses were all devoted to mathematical content knowledge; essentially no class work was devoted to pedagogy. However, there was an effort to introduce new areas of mathematics to the teachers. For example, there were courses on mathematical modeling and on graphs and networks, as well as an emphasis on probability and statistics. Evidence from the time, and from subsequent years, indicated that these institutes worked well for the teachers. All of us involved in the program believe they were successful in reaching their goals.

2. 1974-80: During this period, the emphasis turned to teachers in grades K-8. The initial emphasis was on pre-service course work, with modest work with in-service teachers to validate the pre-service efforts. In later years, the emphasis was on developing problem-solving skills and contacts with local schools. This work was again funded by NSF, and it followed the era of NSF funded SMSG and the development of "new math."

3. 1980-90: During this period, there was increased attention paid to the mathematical preparation of elementary school teachers, with substantial contact with local schools and efforts to change pre-service content courses. One strong theme was that elementary school teachers should study probability and problem-solving.

4. 1990-1996: During this period the focus was on teachers in grades 7-12, and the content work was primarily on mathematical modeling and probability. Again, summer workshops were used, usually for four weeks and some follow-up was required, including preparation of modeling modules, teaching these modules, and reporting back to other teachers at follow-up sessions. Many of these modules are still available for use.

5. 1995-2002: This was the first serious work with whole districts and with most middle schools in these districts. The focus now was on "reform teaching" and on using curriculum materials developed through support of the National Science Foundation. Work with the teachers went on all year, and it included both short summer workshops and follow-up workshops during the year. Teacher leaders were developed, and more emphasis was put on work at the schools during the school year. The intention was to change whole schools, not just some teachers at these schools.

6. 2002-2008: The recent PD work was part of an NSF Math-Science Partnership grant and involved nine school districts and grades K-12. The work was tightly tied to the curriculum that the teachers were using. This work was much more substantial than earlier efforts, and the focus was on improving schools, not just helping individual teachers. A key component of the work for K-6 teachers was to provide substantial support to the teachers for their classroom work. This was partly done through confidential teacher logs, where questions on both the content and the curriculum could be asked knowing these questions would be quickly answered by experts. A series of follow-up workshops was held during the year to reinforce the connections between the content work and the curriculum. Teacher liaisons were developed to tie together the work at K-6 with that of 7-8 and then to also tie 7-8 with 9-12.

Lessons learned:

Based on the history of PD for mathematics teachers in K-12 that was carried out at Indiana University, a few lessons have been learned. Namely,

1. PD to improve teacher's content knowledge does work, and the individual teachers become much stronger mathematically. The teachers in our original NSF Institutes became strong mathematics teachers and most had long careers teaching mathematics successfully. In many cases, they were the best teachers at their schools. On the other hand, such work had limited impact on schools, especially when the teachers involved do not form a critical mass at their schools. Many of the teachers moved to teach at community colleges and some went back to college and got Ph.D. degrees and taught at colleges.

2. To impact schools and large numbers of teachers, it is essential to connect the PD with the curriculum and to develop teacher leaders who will help and lead the other teachers at their schools. It is also essential to involve school administrators in the process of PD and change at their schools.

3. PD works best if it is close to continuous and delivered all year. The impact of summer workshops needs to be reinforced during the year. Most of this work needs to done at the schools and have a direct connection to the teacher workplace. Also, it is critical that teacher leaders be developed to be available to all teachers at the school and that they play a key role in designing and carrying out the PD work.

A key critical research question which remains open is:

- How does one know if a given mathematics teacher is an effective teacher of the CCSSM?

Related questions are:

- What courses and experiences help teachers become effective teachers of CCSSM?

- How does one know who will be an effective teacher leader—one who will be able to help other teachers become more effective?

John C. Mayer

Greater Birmingham Mathematics Partnership

Both in-service professional development (PD) and pre-service teacher education will be challenged to respond to the widespread adoption of the CCSSM. My main concern is that a focus on topical content standards will marginalize process standards. This will be particularly important as some states' educational spokespersons "assert" that they are "98 percent" in accord with the CCSSM. To address this concern, based upon my experience with the Greater Birmingham Mathematics Partnership, I would make sure that both PD (and teacher education) should rest on three pillars:

- Content knowledge courses taught so as to model the mathematical practices and processes that promote student learning.
    - In-service (and pre-service) teachers must experience mathematics as learners in a pedagogical context that supports both process and content standards.
    - Problem-solvers value problem solving.
    - (Requires some transformation of IHE mathematics courses for teachers.)
- Robust in-school professional learning communities, both within and across grade levels, in which teachers focus on their practice as professionals.
    - Practice includes implementation of curriculum, sharing of experiences with specific lessons, design and analysis of authentic assessments, and modification of lessons to address weaknesses in student learning.
    - PLC meetings across grade levels promote focus on trajectories of students and on content threads.
    - School- or district-based mathematics coaches would be most effective.
    - Self-perceived high levels of content knowledge and self-awareness of knowledge deficiencies both impede sharing of teaching practices.
    - Transformation of instructional practice takes time.
- Periodic short but intensive (summer?) mathematics content seminars where in-service teachers have the life-long opportunity to engage in mathematics.
    - IHE faculty can help keep these both inventive and relevant.
    - Regular interaction as problem-solvers may make it easier for teachers to bare their teaching practices to each other.

GBMP in its Phase I implementation and research (2004-2010) focused on the first pillar of the above triad: intensive summer mathematics courses for middle school teachers. The courses were transformational for teachers as learners. With under 300 middle school teachers in the area districts served, this potentially was an effort at scale. Student learning did improve significantly in those classrooms where the modeled inquiry-based pedagogy was implemented by teachers. The omission of an equally robust component developing school-based PLCs was identified as a major factor in faithful implementation NOT being widespread in Phase I. This is being corrected in Phase II with the incorporation of second pillar: school-based PLCs. The third pillar is something that could be jointly implemented by a district and a cooperating college or university.

Sketch of a Plan for K-4

- Year 1 and ongoing: Three intensive summer courses in critical K-4 content identified by CCSSM over three years.
    - "Critical" is content that has been identified in research as areas of conceptual weakness in elementary teachers of mathematics, e.g., models that support division of fractions.
    - Model evidence-based pedagogy.
    - Provide opportunity to discuss evidence.
    - Offer at sustaining level for new inductees.

- Year 2: Establish school-based PLCs by grade level and across grade levels.
    - o Early goals are identifying threads in CCSSM, identifying curriculum supporting CCSSM, supporting and assessing both content and process learning by students.
    - o First summer course sets stage for first PLCs.
    - o Time for PLC meetings in school day.
    - o District math coaches.

- Year 3: Establish partnership with local IHEs.
    - o Align IHE mathematics courses for pre-service elementary teachers with CCSSM and coherent development of mathematical concepts.
    - o Begin ongoing mathematics seminars for in-service teachers with IHE faculty contributing.

A Few Key References

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Monica B. Mitchell

MERAssociates

A body of literature is emerging that considers the role of the district context, including policy, governance, and general characteristics, in understanding the complexities of improving K-12 mathematics education (Cobb, 2008; Ogawa, Sandholtz, Martinez-Flores & Scribner, 2003; Spillane, 2000; Spillane, 2004). Recent research related to scaling mathematics education reform, interventions as well as adoption and implementation of curricular materials, elucidates the influence of the district context on instructional practice (Cobb, McClain, de Silva Lamburg &Dean, 2003: Cobb & Smith, 2008; McClain, Zhao, Visnovska & Bowen, 2009; Stein & Kim, 2009).

The standards-based reform movement in the 1990s and 2000s saw significant district involvement. These systemic initiatives focused on a theory of action based on system-wide alignment of content standards (NCTM and state), professional development (PD), instructional materials, instructional practice, and assessment to affect improvements in student learning and achievement. Similarly in the wake of No Child Left Behind, alignment likewise is foreground as part of the legislation to advance reform primarily through accountability (Porter, 2009). Within the high-stakes testing environment, school districts have exercised increasing authority for instructional policy to influence classroom instruction (Elmore & Fuhrman, 2001; Spillane, 2004) and local implementation agents at the district level use a variety of policy-making tools to influence policy implementation that has a direct bearing on classrooms. As part of a larger research study on teachers' use of standards-based instructional materials (King, et al., 2011), the use of pacing guides for middle school mathematics was found to be widespread in urban school districts[1], and in many cases, its use represented the central policy instrument for implementation of instructional materials mandates. Specifically, the pacing guide attempts to align materials and practice with standards, including appropriate and adequate content coverage, and provides focus for organizing PD. Should the implementation pattern of the standards-based movement hold true for the CCSSM, alignment will continue to play an explicit and prominent role.

Yet a well-aligned system, although necessary, may not be sufficient to support standards implementation. In the case of the pacing guide study, the participating district represented a well-aligned system as well as a mature implementation site.[2] Despite extensive PD tied closely to standards-based instructional materials as a consequence of the district's NSF-funded Local Systemic Change initiative, the district pacing guide deviated significantly from the materials and represented a major point of departure from curricular fidelity (Mitchell & King, 2010). The intended curriculum as embodied in the district pacing guide can compliment or interfere with the goals and objectives of standards-based reform and often send mixed messages associated with standards.

The needs of districts to support implementation that directly influence classroom practice extend beyond the sole issue of alignment. The decision-making surrounding the pacing guide reflected multiple factors and often conflicting tensions. As expected, external alignment with the state standards was intentional and explicit. However, the need to satisfy internal alignment with the district vision of mathematics required at the middle school level, in this case commitment to statistics and probability as a key strand, mitigated the extent of external alignment. The district's perception of students' mathematical histories and background related to limitations in computational proficiency and algebra readiness contributed to a redistribution of content strands across grades. As a result, number sense was expanded at the 7th grade and algebra diminished qualitatively at both the 7th and 8th grades, ultimately resulting in the elimination of 40 percent of the 8th grade curriculum. Finally, organizational issues of time constraints and staffing contributed to reordering units within grade, assigning units to another grade, and elimination of units entirely from the curriculum.

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[1] Sixteen urban school districts were surveyed to gauge the prevalence of mathematics pacing guides in the urban setting. All but one (94%) of the districts we surveyed reported using mathematics pacing guides. The districts represent some of the largest urban school districts in the country having combined student enrollment approximating 50% of all students in urban public schools in the United States.

[2] Based on the Survey of Enacted Curriculum indices used in the study the district's middle school mathematics program in terms of instructional materials, state standards, and state assessment exceeded the national benchmark indicator of .24 for 'good' alignment.

Surprisingly, attention to the integrity of the mathematics to support its cumulative progression, and the integration of key fundamental concepts associated with specific topics, did not figure prominently in the decision-making process. In some cases, modifications did not affect the integrity of the mathematics. While in others, the coherence of the mathematics suffered. For example, to accommodate time constraints, the district removed variability in the pacing guide as a fundamental concept to develop conceptual understanding of central tendency. In another instance, the district reordered the unit on distance two units behind the unit on symmetry and transformations, instead of preceding it as a prerequisite as originally designated in the design of the materials.

Districts need guidance and support to effectively balance and address competing tensions and realities inherent in implementation. As PD is designed and implemented, the multiple decision-making factors influencing district instructional policy must be considered. Effective PD should be responsive to district needs and context and informed by these realities. To what extent does PD support and facilitate negotiation of the district's vision of mathematics? How will PD address issues of student proficiency in skill development and algebra readiness, particularly at the middle school level in urban settings?

Importantly, although alignment and other issues are considerations for district decision-making, these issues cannot take precedence over explicit attention to mathematical coherence. The coherence and integrity of mathematics must be emphasized in PD as a priority, not as an afterthought. The progressive development and cumulative nature of key content areas must be well understood so as adaptations and modifications occur, and they will, at the district and classroom level, the integrity and coherence of the mathematics will be preserved. More guidance and support in this area is crucially needed. Involvement of mathematics content expertise (e.g., mathematicians) would be appropriate for this role. The content focus need also must be balanced with the pressures of alignment as well as competing tensions and issues confronting districts as they develop and implement instructional policy around the CCSSM.

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The call for this brief acknowledges four basic research-based principles for designing professional development (PD) that works. These principles are similar to, but not exactly the same as, the five identified by Garet et al (2001):

- Duration – sufficient number of hours of PD experienced over an extended period of time so that participants can learn, try out their learning, and learn some more (similar to the first principle offered in the call, but making clear that it's not just the amount of PD but that PD is offered interspersed with opportunities for participants to try out what they are learning and then to learn more)

- Content Focus (essentially identical to the second principle offered)

- Coherence (which includes the third principle offered, but extends it to not only being aligned with school improvement priorities, goals and other initiatives/reforms, but also aligned with participants' current state of knowledge)

- Collective Participation, which calls for participants to experience the PD in school teams or all teachers from a given grade and subject (here, there is a difference from the fourth principle in that the focus is on characteristics of the PD rather than the fourth principle's focus on the outcomes of PD), the idea being this provides teachers an opportunity to discuss what they learned, share ideas and build a learning community around ideas in the PD

- Active Learning, meaning that participants in PD should be actively engaged in building their own knowledge (an additional principle), engaging in such activities as being observed and receiving feedback, analyzing student work, engaging in discussion and problem solving, rather than being the passive recipients of knowledge provided in PD.

In designing PD in support of implementation of the CCSSM, at least some of the content focus should be on making sure (a) teachers understand what the CCSSM standards call for and equally important, what content they do not call for and should not be taught. In addition, (b) the PD should help teachers understand how the content messages of the CCSSM are alike and different from the teachers' current content practices. The analysis of discrepancy needs to be addressed at the individual PD participant level.

One methodology that could be used to analyze the content message of the CCSSM and how it is alike and different from the content practices of an individual teacher, is the Surveys of Enacted Curriculum (SEC). The SEC in mathematics provides a language for describing the content of an intended curriculum or an enacted curriculum. The language consists of a matrix of topics by cognitive demand (183 by 5). The SEC has been used to compare and contrast the content messages of the CCSSM to the content messages of current state content standards, state assessments, NAEP, NCTM, standards from high-achieving other countries, and current content practices of US teachers (Porter et al, in press). PD has been designed to help teachers examine how their instructional content practices are alike and different from state content standards and state tests, and a randomized field trial showed that the PD had effects on teachers' content decisions (Porter et al, 2007). This approach is consistent with recent studies on using data to assist teachers in shaping and improving their instruction.

One idea for doing such PD at scale would be to use distance education. The SEC is completed online. Reports of how a teacher's practices are alike and different from the CCSSM can be delivered online. There might be, in addition to the online PD experience, opportunities to convene teachers of mathematics at the school level to talk about the implications of the discrepancies between their content practices and those of the CCSSM. These school-level discussions could be facilitated online as well.

The following articles have influenced my thinking:

Carpenter, T.P., Fennema, E., Peterson, P.L., Chiang, C., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal*, *26(4),* 499-531.

Desimone, L. (2009). How can we best measure teacher's professional development and its effects on teachers and students? *Educational Researcher*, *38(3),* 181-199.

Kennedy, M. M. (1998). *Form and substance in inservice teacher education* (Research Monograph No. 13). Arlington, VA: National Science Foundation

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Porter, A., McMaken, J., Hwang, J., & Yang, R. (In Press). Common Core standards: The new US intended curriculum. *Educational Researcher.*

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A.

The most difficult part of the sequence design-implementation-assessment of a mathematics professional development (PD) program in an education system at the district or state level is obviously the implementation. Both the design and assessment are challenging problems, but are more easily controlled by experts in their specific areas. The implementation comprises the flow of knowledge about PD and teaching mathematics out from the expert communities to the constituencies of stakeholders, which are very diverse. As a result, the implementation process almost invariably involves reopening discussions that the design process might have closed within the boundaries of expert judgment to introduce perceptions and priorities from lay interested parties. These range from politicians and policy makers to parents of students, and various layers of administrators, among others.

Implementation of a program is a case of use of knowledge contained in the design and the relevant disciplines, which naturally gives more sophisticated attention to the focus of its technical content than it does to the details of the various contexts in which it might be used. In this case, the technical content is about the ways in which knowledge of teaching math is acquired and applied in classroom settings; on how this relates to the prior knowledge and background of teachers; and on the settings and dynamics through which teachers do their teaching using these approaches. However, just as important for the success of programs to improve student learning of mathematics are the effects of contextual circumstances such as the organizational and managerial practices of schools and districts, teachers' labor conditions, the prevalent public discourse on the effectiveness and legitimacy of public schools used by politicians and policy-makers, among others, on the application of the technical content of the program design.

All this leads to the need for including in the design an analysis of the effects of the use of new and improved teaching approaches on those constituencies. Since teaching is a social practice, whatever teachers learn to do that might change how they approached their activities in the past almost surely will have a ripple effect across the organizational and institutional arrangements of schools. Some of the recommendations for best practices that already exist include, for example, more time devoted to PD and forms of teacher collaboration, and formation of teaching communities, among other things. All of these practices have potential consequences for administrators' expectations, distribution of effort, parents' perceptions, and so forth. All of these constituencies, including the teachers themselves, must see the realization of value that these changes imply for them. If the manner in which the priorities of these constituencies are affected by the application of what teachers learn is not thoroughly understood during the design and planning stages, the implementation will almost certainly fail. As a matter of fact, items 3) and 4) of the NSDC 2009 report are more or less generic versions of this point.

This has consequences for assessment of quality as well in the sense that a broader set of criteria may need to be considered in the assessment having to do with the values contained in constituencies' priorities.

In sum, in order to implement a PD program at a district or state scale, sufficient understanding of the "social terrain" in which implementation of teacher learning will occur is indispensable and should be acquired during the design and planning stages to anticipate the need for priority alignment with all constituencies.

B.

An idea in this area, not very novel, but I believe quite important is the following: any scale up of program implementation requires relatively small scale but solid pilot experiences that are well implemented and understood. The critical issue in pilot experiences is that the key variables of the underlying design model are observable, and more or less controllable, so that the assessment of its results is very clear. At this point in time, a pilot experience using the latest results from research on PD for teaching mathematics should be carried out. The best wisdom on content, intensity, alignment with schools priorities, communities of teaching—to name the four key findings of the NSDC report—plus several other issues derived from knowledge of relevant constituencies, should be brought to bear on the pilot design and implementation. Specialized observation approaches should be put in place in order to derive clear lessons for scale up.

The implementation of programs is path dependent, meaning that what has been attempted in the past constrains what can be done in the future, because the experience of constituencies with it develops alongside. Therefore, the sequence of pilot experiences, assessment and re-design until full-scale implementation is reached is of critical importance. The crucial issue is step-by-step collective learning for all those with a stake in the outcome since the technical quality of the program must be well integrated with its legitimacy for it to succeed.

C.

Most of what I have learned about these issues comes from my experience with efforts at performing knowledge translation (KT) in health care. There are many analogous challenges for teachers' PD. The purpose of KT is to bring the benefits of promising new results in health to patients. For that to happen, doctors, nurses, and other health care professionals must learn to implement the new treatments setting up a PD challenge with similar contours to the one for the improving the teaching of math. However, new research results often bring about ripple effects for how professionals in various roles perform their work and simple absorption of new knowledge is not sufficient for the potential benefits of the new results to accrue. Two articles with references on this are:

Rogers, J. D., Martin, F. and KVM-KT Task Force (2009). Knowledge translation in disability and rehabilitation research: Lessons from the application of knowledge value mapping to the case of accessible currency. *Journal of Disability Policy*, *20*(2), 110-126.

Rogers, J. D. (2008). New strategies for knowledge translation. In E. Thorson and J. C. Parker (Eds.), *Health care communication in the new media landscape*. New York, NY: Springer Verlag.

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In this short piece I describe what I think it would take to assess the quality of mathematics professional development (PD) by linking teacher behavior to student learning. In doing so, I try to take on the role of a methodologist who has an expressed interest in linking theory to implementation. Researchers in mathematics education share a common goal – improving the teaching and learning of mathematics for all. To attain this goal, we engage in complex activities based on conceptual knowledge drawn from mathematics, the philosophies of mathematics and education, the psychology of learning and human development, theories of instruction, organizational theories of the settings in which learning occurs, research on policy developed to support learning, and methodologies that warrant claims for learning. Often these components are treated as intellectually separable to afford single researchers the opportunity to address highly focused research careers. One natural dilemma associated with this theoretical and empirical splitting is that warranted claims can only be made at a single level of analyses (about learners, or about teachers). This, I believe, is counterproductive when the central questions of theory, research, practice and implementation are cross-level in nature. These questions can only be resolved by linking research on teaching with research on learning (in the organizational settings we call classrooms and schools). In order to better link theory and practice, a critical mass of research in mathematics education needs to be reconceived to be multilevel in its theoretical formulation and empirical articulation. Few researchers in mathematics education have approached their research in this fashion (a recent but critical exception includes the work of Hill, Ball and Rowan, 2006). Their work uniquely focuses on theoretical and empirical linkages between measures of teacher-knowledge for teaching and student achievement in mathematics. Research in the development and testing of multilevel models has increased dramatically in the past 30 years (Raudenbush & Bryk, 2002), yet there have been relatively few efforts made that provide a broad multilevel theoretical framework for mathematics education research, or for the impact of PD linked to student learning. This is seen in the consistent way we think of mathematics education. For example, research work presented in the recent *Handbook of Teaching and Learning Mathematics* (Lester, 2007) continues to parse teacher knowledge, instruction and student learning as separable empirical acts, as though they are not interactive theoretically (exceptions being chapters by Hiebert & Grouws (2007) and Franke, et al (2007)). As such, we have failed as a research community to develop needed multilevel theory to support the scaling of curricular interventions in mathematics. This generates issues associated with how we theoretically, methodologically, and analytically approach the generation of insights within educational contexts and their study.

Theoretically, we in mathematics education tend to study learning as an act "almost" separate from teaching. Methodologically, we organize our participants according to their individual or group status, but rarely at both levels simultaneously. Analytically, we examine data in argumentative parallelisms, either by individuals or groups to which we are methodologically bound, but ultimately not in the way that data actually exist in situ (assuming, for example, that data are collected from students within classrooms). The limitation arises in that our theoretical idea of learning is disconnected, or not as connected as it could be, to our elements of methodology and later analysis. We, as mathematics education researchers, often speak of needing to align theory, method, and interpretation, but often fail to do so in our conceptualization of learning and teaching. I define multilevel mathematics education research as "mathematics education research that links teacher and student behavior, and honors both of these analytic units and the linkages across these units theoretically and empirically." This framing is, I believe, one way to move forward in the study of the potential impacts of PD.

Multilevel theory building represents a substantial challenge to mathematics education researchers trained to think in a "micro" fashion (i.e., developmentalists in general and constructivist mathematics researchers in particular, for example, Simon, Steffe, and Thompson among others), or to think "macro" (like sociologists, or socio-cultural theorists, for example, Cobb, Yackel, Nasir and others), but not to think "micro and macro" simultaneously (Barr & Dreeben, 1983). This is challenging because the act of education exists at both the macro and micro levels, and working at both levels simultaneously requires specific training and new approaches (that are not simply borrowed wholesale, or even partially, from psychology or sociology).

Given the training of those involved in mathematics education research, and the tradition of research in the community, cross-level theory building is a challenge. However, the problems of PD and of curricular interventions are invariably multilevel in nature. Students are nested in groups, and groups occur in classrooms where instruction is provided. When instruction is provided to groups of individuals (in their classroom or remotely), then the problem under study can be configured so as to address this nested or multilevel formulation. Or, in a more conventional scenario, when a teacher provides instruction to a whole class, consisting of individual students doing individual work and communicating this work to each other, a similar set of nested levels exist. The research problem should be reframed as a multilevel issue, and must be addressed with methods and theories about nested or multilevel structures.

Two Influential Readings:

Cohen, D., Raudenbush, S. W., & Ball, D. L. (2000). *Resources, instruction and research.* Seattle, WA: The University of Washington, Center for the Study of Teaching and Policy.

Cronbach, L. J., & Others (1976). *Research on classrooms and schools: Formulation of questions, design and analysis*. Stanford, CA: Stanford Evaluation Consortium, ERIC Document: ED 135 801.

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I. What would it take to design, implement, or assess the quality of mathematics professional development that would support the implementation of the CCSSM content and practices?

I will address issues of design and implementation because my own professional development (PD) work has led to think about them, more than assessment. I am quite new to the PD enterprise and have many more questions than answers about this sort of teaching & learning/development. Relative to CCSSM content and practices, I would note that the content is explicit and detailed in the document but the practices are explicit in idea form only. To press the point a little bit, I believe that all the talk about "what the practices are" is misguided and misleading, as they are currently nearly empty containers awaiting content. They are proposals awaiting real meaning.

Given the "systems" focus of the conference (an entirely appropriate framing), any serious PD effort in support of the CCSSM must be extensive (at substantial and growing scale) and sustained temporally and financially. If we are optimistic about the nature of new assessments designed to align with the CCSSM, the main missing piece of the "national progress puzzle" is PD. I agree with Jim Hiebert and others who argue that we have our national priorities wrong about the quality of mathematics teaching: We should not be looking for the right people but developing and testing structures that help good teachers grow to become better teachers, in a continuous way. I expect that those structures will be physical (like Delaware's annotated lesson plans) and/or social/cultural in nature, the latter like teacher study groups, aspects of the culture and practice of Lesson Study, and the Boston Residency program (from the little that I know about it). The dual dimensions of physical artifacts and patterns of social interaction correspond to the two principal dimensions of the situative perspective on learning.

A national system of PD should emerge from a structure of intentional experimentation at some scale. We have lots of good ideas and worthy intellectual leaders but we have, as I see it, no clear empirical base for system design, beyond broad principles such as those outlined in your invitation. We need a process to narrow the field of compelling ideas and structures (e.g., annotated lesson plans) and associated lead researchers to a small number and a funding mechanism to support their work to "make their empirical case," relative to clear and public assessment guidelines (i.e., what would demonstrate progress in a broadly compelling way). At best, the competition to demonstrate success should not be limited to one cycle of competition; PD leaders should have periodic access to support to demonstrate the efficacy of new and compelling structures.

It is hard to express a vision for such a system in the current climate of most K-12 education in so many states and regions. The effects of budget cuts in schools and teachers are not simply that resources are scarcer, though increasing class size from teacher layoffs have had and will have serious effects. An even greater effect is to decrease dramatically teachers' orientation toward professionalism—that is, as being members of valued profession that uses its knowledge and skill to accomplish work that is highly valued in the culture. A sense of professional status, felt personally and continually reinforced by social, cultural, and economic environment, is essential for successful PD at scale. The poor climate for professionalism in teaching cannot be a reason not to imagine and design these systems, but neither can it be ignored.

A second challenging dimension of the climate for developing and sustaining PD systems is the broad American cultural and political expectation for immediate and dramatic effects in education, when all we know points to gradual and incremental change, even when things "go well." Substantial effects at scale will only emerge if the pressure to show dramatic and immediate "turn around" can be reduced or rebutted.

II. Describe, in some detail, one idea you have for how professional development can be done at scale.

I have one idea for actions that might advance the general ideas sketched above. A funding agency (National Science Foundation seems the most likely candidate) would provide substantial multi-year support (say 5 years) to a small number (say, 5 to 7) state-wide consortia to implement a PD system at that level of scale. Part of their task would be to develop a feasible and plausible plan for sustained function beyond the initial period of financial support from the funding agency. Proposals would articulate the principal structures (material and social), provide evidence for their promise (at small scale), describe the statewide personnel and structures that already exist and can be engaged, and include promises from leaders that this activity would be their professional life for the next five years. Proposers would not be expected to engage all teachers in their states during the period of initial support, but rather to present and implement a plan for reaching increasing and significant numbers of teachers working in all relevant contexts and communities. For university faculty, this would mean an official leave sanctioned by their administration with no loss of status or position.

An important element of this approach would be the design and content of the RFP that would generate promising proposals. The group (governing board?) leading this effort must be led by, indeed dominated by, the best we have nationally with the ideas of PD and its implementation. To some extent, the promise of the proposals will be a function of the quality of the RFP. The RFP must determine guidelines for reach (numbers of teachers involved across the period), PD character and quality, and evidence of impact on classroom teaching. It could also require that "winning" states engage smaller number of leaders and teachers in adjoining states as one vector for growth beyond the one state. Service on the governing board would preclude involvement in any team developing and submitting a proposal. Funding for the duration of the research cycle (5 years) must be assured.

One major problem with this proposal is that the uncertain (to say the least) prospects for states to assume the financial support (at any substantial level) for the system when the initial period of agency funding ends. I can imagine efforts (possibly successful) to get written promises from governors and/or legislatures in advance, but I am not sure what such "guarantees" would actually mean.

III. Identify a small number of articles that have influenced your thinking.

I have little to say; sorry! Beyond the many references that have argued the basic points that high quality PD in mathematics needs to (1) include and grow from teachers' work on well-chosen mathematical tasks and their discussion of their work, (2) provide ways for teachers to relate their PD activities to their current practice, (3) support teachers' discussion of and sense-making about what their students actually do and say in their classrooms, and (4) ground that sense-making in the actual work (written and oral) of their students, I have not learned much from any specific reference. That said, I may not be reading widely or deeply enough.

Thomas M. Smith

Vanderbilt University

In collaboration with Paul Cobb at Vanderbilt and Kara Jackson at McGill University, I have been working to understand what it takes to support mathematics teachers' development of ambitious instructional practices on a large scale. Research in mathematics education and related fields has made considerable progress in recent years in documenting learning progressions in specific mathematical domains (Carpenter, Fennema, Franke, Levi, & Empson, 1999; Lehrer & Lesh, 2003), in contributing to the development of instructional materials and associated resources (Stein, Remillard, & Smith, 2007), in delineating ambitious instructional practices that support students' development of key mathematical ideas and involve more students in that learning (Franke, Kazemi, & Battey, 2007), and in investigating professional development (PD) that supports teachers' growth in these practices (Ball, Sleep, Boerst, & Bass, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kazemi & Hubbard, 2008; Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2010). These advances have had limited impact, however, on instruction in most US classrooms.

Findings from a number of studies conclude, however, that inquiry-oriented curricula, such as the Connected Mathematics Project (CMP), when implemented effectively, improve students' conceptual understanding and problem solving more than instruction using traditional curricula, while having no negative effect on the development of computation skills (Cai, Nie, & Moyer, in press; Schoenfeld, 2002). Despite these findings, a number of large urban districts have moved away from inquiry-oriented curricula recently, when either state test scores have not improved, or teachers or community groups have pushed for a more traditional curriculum. This suggests that the forms of support that districts and schools put in place when they adopt inquiry-oriented curricula are crucial to successful implementation and to sustainability. Paul, Kara, and I are currently testing, revising, and elaborating a comprehensive set of hypotheses and conjectures about district and school supports for improving classroom instructional practice in the context of implementing inquiry-oriented curricula of the type that we expect would broadly align with the CCSSM. I will briefly describe the kinds of supports we think are necessary to support curricular and instructional reform at scale, as well at the literature that these ideas build upon.

We believe that effective implementation of the CCSSM will require the creation of a coherent instructional system at the district level for supporting mathematics teachers' development of ambitious instructional practices. Newmann et al.'s (2001) and Bryk et al.'s (2010) findings, as well as our current work, suggest that improving the quality of instruction at scale requires the establishment of a coherent instructional system comprising: 1) explicit goals for students' mathematical learning; 2) a detailed vision of high-quality instruction that specifies concrete instructional practices that will lead to the attainment of the learning goals; 3) instructional materials and curriculum frameworks designed to support teachers' development of these specific practices; 4) district teacher PD that focuses on the specific practices, is organized around the above materials, and is sustained over time; 5) school-based professional learning communities (PLCs) that provide ongoing opportunities for teachers to discuss, practice, and adapt the practices that are introduced in district PD; 6) assessments aligned with the goals for students' mathematical learning that can inform the ongoing improvement of instruction and identify students who are currently struggling, and 7) additional supports for struggling students to enable them to succeed in mainstream classes.

Our current work in four large urban districts highlights the challenges of developing coherent instructional systems. Leaders in all of our partner districts have articulated explicit goals for students' mathematical learning and a vision of high-quality mathematics instruction that specifies fairly concrete instructional practices. Several have developed elaborate curriculum frameworks and invested in mathematics coaches, while others are relatively sophisticated formative assessments. We are finding, however, the weakest element of the instructional systems in each district is teacher PD. Current research indicates the value of organizing PD around a limited set of concrete, high-leverage practices (Ball, et al., 2009; Grossman et al., 2009; Lampert, et al., 2010; Lampert & Graziani, 2009). None of our districts organizes PD in this manner and linkages between district and school-based PD are weak at best.

A coherent instructional system can also support the development of strong professional relationships among mathematics teachers in a school (Bryk et al., 2010). The resulting trust, mutual accountability for student learning, and access to others' expertise are at least as important as teachers' perceptions of value of the instructional reform in driving instructional improvement (Bryk & Schneider, 2002; Frank, Zhao,

& Borman, 2004; Penuel, Riel, Krause, & Frank, 2009; Spillane & Thompson, 1997) and taking the reform to scale. We are finding in our own work, however, that many teacher lack expertise among those they rely on in their networks, and that while districts are increasingly using coaches as a primary means to support teachers' learning (Frank, et al., 2004; Louis & Kruse, 1995; Penuel, et al., 2009), we have found that school-based coaches often have little more expertise in implementing an inquiry-oriented curriculum than the teachers they are trying to coach, and that while coaches hired at the district-level may have more expertise, they are often serving too many schools simultaneously to have a substantial impact on teacher practices. Thus, while coaching is a promising means for providing teachers with access to expertise as they work to adopt new curriculum and instructional routines, the selection, training, and allocation of coaches are key components to facilitating teacher change.

We have also been exploring the role of instructional leadership in implementing challenging curriculum at the scale of a district. Current research provides contradictory guidance on school instructional leadership. Some researchers argue that it is sufficient for school leaders to understand general, content-independent principles of learning and instruction (Glennan & Resnick, 2004) whereas others contend that school leaders responsible for implementing an ambitious mathematics curriculum need a deep understanding of mathematics, students' mathematical learning, and teacher learning (Nelson & Sassi, 2005; Stein & Nelson, 2003). Initial findings from our work suggest that PD based on the first view is too abstract and that most school leaders are not able to connect general principles to concrete instructional practices. We conjecture that supporting school leaders to recognize a small number of high-leverage, concrete practices will enable them to effectively and realistically press to improve the quality of instruction.

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Mary Kay Stein

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What would it take to design quality mathematics professional development that would support the implementation of CCSSM?

High-quality professional development (PD) for improvement at scale (i.e., in an entire district) requires coordination across levels of the system. Unless the top district leadership, principals, coaches, and teachers are "on the same page," implementation will be extremely variable. In my judgment, the anchor of a coordinated system should be student learning: If we want students to have the opportunity to learn the content and practices of the CCSSM, what does classroom practice need to look like? If we want teachers to be able to design and carry out these classroom practices, what kinds of supports for teacher learning must be built into the system?

The problem of teacher learning cannot be treated on a teacher-by-teacher basis. Rather, the design of high-quality PD must be viewed as a problem of organizational learning. District leaders have to develop a vision of quality instruction and a theory of action for how to support it district wide; principals must learn how to monitor, support, and arrange resources for PD; coaches must learn how to help teachers learn.

Even if all layers of the system are on board, there are still bound to be problems of "translation" that happen at the intersection of different communities of practice. For example, as a "curriculum framework" is passed from district leadership to principals to coaches, one can expect that each community will re-interpret the framework based on their own working knowledge. Time needs to be built in for shared "meaning making" at these various boundary crossings in order to coordinate meanings so that the system can work together in a synchronized fashion.

One idea for how professional development can be done at scale (whole district)

First, district leaders must select a curriculum that is aligned with CCSSM. Ideally the curriculum will also be "educative," meaning that it has been designed to be supportive of teacher learning. By helping teachers to understand the rationale for the instructional tasks in the curriculum (i.e., the mathematical point of each task and how and why the task can surface important student ideas) and to anticipate how students might respond to the tasks, such curriculum materials can assist teachers to prepare for lessons that take account of and build on student thinking.

District leaders should be prepared to dedicate resources to PD surrounding the curriculum materials. Ideally, each school will be assigned one mathematics coach (or two half-time coach/half-time teacher positions). Coaches should be expected to conduct the following kinds of activities: conducting (a) "initiating sessions" to help teacher prepare for curricular content that they will be teaching at the beginning of each new unit of the curriculum; (b) individual in-class co-teaching and coaching; (c) grade-level meetings with teachers; and (d) walk throughs with principals to acquaint principals with the features of high-quality instruction and their purposes.

The coaches themselves should be selected based on an assessment of their instruction, not by years of experience or the vote of their colleagues. The selection and assignment of coaches should be carried out jointly by the district mathematics leadership team and the principals. Coaches will need to be "trained" in terms of the new curriculum and the mathematical ideas underlying it, as well as how to support teachers as learners. Ideally, a trajectory of teacher learning in relation to the curricular materials will have been mapped out (e.g., non-users to mechanical implementation to canonical implementation to maverick teachers capable of altering the curriculum but preserving its intent). These "markers" can then be used as milestones to judge where individual teachers are, and the kind of assistance that they need to move to the next level.

Principals should be expected to be managers and supporters of instructional improvement. As such, they should attend the PD alongside their teachers so that they can learn what is expected of teachers, as well as what their role should be in supporting teachers' development. By understanding where their teachers are in relation to where they need to be, principals can make better judgments regarding the allocation of resources. By having an informed understanding of the kind of instruction that is needed to bring student learning about, principals can become better monitors and evaluators of teachers. Principals must have the authority to hold teachers accountable for trying new practices and, over time, for improvement.

Grade-level meetings (or other kinds of professional learning communities) cannot be expected to bring about change absent attention to (a) what is discussed in those meetings; and (b) the expertise levels of those in the group. Thus, these meetings need to have agendas related to what teachers are doing in the classroom and, ideally, the participation of a principal or coach to hold teachers accountable to those agendas. Second, communities function best if there is some "asymmetry of expertise," that is, it is best to have at least one expert teacher in the group who can model what is expected and, in general, raise the level of discussion.

Finally, care needs to be taken that teachers do not receive mixed messages. Mixed messages can come from high-stakes assessments that are not aligned to the curriculum or from other initiatives that work at cross purposes to the mathematics initiative. It is the district leadership's responsibility to guard against this.

Articles/Books that have influenced my thinking

Brown, M. W. (2009). The teacher-tool relationship: Theorizing the design and use of curriculum materials. In J. Remillard, G. Lloyd, & B. Herbel-Eisenmann (Eds.), *Teachers' use of mathematics curriculum materials: Research perspectives on relationships between teachers and curriculum*. New York, NY: Routledge.

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Marilyn Strutchens

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Transforming East Alabama Mathematics (TEAM-Math), a National Science Foundation funded Targeted Mathematics Science Partnership from 2003-2009, will be used to exemplify a well-designed systemic change effort. The TEAM-Math partnership included Auburn University, Tuskegee University and 14 school districts in east Alabama. A central goal of the partnership was to ensure that all students, including African-American and other historically underserved groups, receive high-quality mathematics education. This required a comprehensive set of strategies addressing all aspects of the educational system. From its inception, the thinking and design of TEAM-Math was informed by lessons learned from related projects and from the research literature. A primary source of insight was the Mathematics: Application and Reasoning Skills (MARS) project (Campbell, Bowden, Kramer, and Yakimowski 2003). The TEAM-Math co-director, Marilyn Strutchens, was a member of the MARS project team, and we replicated a number of the components of MARS, including school teacher leaders, development of a curriculum guide, summer institutes, school administrator briefings, and parental involvement. We also used the cohort approach for schools to enter the project. What follows is a brief description of some of the key principles derived from lessons learned in the MARS project and other research.

Curriculum Alignment. Representatives from each of the partners met to create a common curriculum guide aligned to state and national standards and incorporating research and best practices (TEAM-Math 2009b). The curriculum guide was subsequently adopted by the districts, in some cases with minor modifications. The curriculum guide continues to be updated on an annual basis. In addition, a partnership-wide textbook adoption committee was formed to provide guidance to the partners, and it recommended a co-adoption model in which a more-traditional textbook series was used in conjunction with one of the more-investigative sets of materials developed with NSF support that were more in alignment with project goals (*Investigations in Number, Data, and Space* for grades K-5; *Connected Math Project* for grades 6-8, and the *Interactive Mathematics Program* for grades 9-12). This approach was taken since the new textbooks would be implemented before teachers would have time to participate in the training necessary for successful implementation of the NSF materials. Most of the school district partners adopted the recommended materials. This common curriculum has provided a firm foundation for other partnership activities.

Leadership. The partnership used a distributed leadership model (cf. Spillane 2000) as a foundation for the organizational structure. The principle investigators believed that it was important for leadership to be shared, thus including the voices of teachers, administrators, mathematicians, mathematics educators, and evaluators. The project had a committee for each major area of activity: professional development (PD), teacher preparation, outreach, and evaluation. Each committee consisted of at least two representatives from the K-12 partners (two teachers or a teacher and an administrator), at least two mathematicians, at least two mathematics educators, and graduate students. This structure enabled project leaders to keep the needs and goals of the schools in mind as they advocated change in schools and across the districts. Moreover, mathematics educators, mathematicians, and their graduate students attended bi-weekly seminars that focused on issues related to teacher change; national, state, and local policies involving mathematics education; and other factors related to the goals of the project. These seminars helped project leaders to have a somewhat united front with the teachers during PD sessions.

Professional Development. Research related to helping teachers assist students in reaching their full mathematics potential, raising teachers' awareness of students' needs, both academic and cultural, and providing teachers with the knowledge to integrate assessment with teaching so that they are constantly aware of students' progress and whether or not what is being taught is understood (Bransford, Brown, and Cocking 1999) was foundational to the PD that was provided to teachers. One of the main goals of the project was to produce an articulated school effort to enhance student motivation and achievement by improving teachers' attitudes toward, and use of, reform practices—i.e., those consistent with the recommendations of *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics [NCTM] 2000). The practices are student-centered, and contain the following characteristics: 1) Instructional scaffolding is provided for students that allows them to move from what they know to what they do not know (Ladson-Billings 1995; Carpenter, Fennema, Franke, Levi, and Empson 1999; Carpenter, Franke, and Levi 2003); and 2) Teachers use a variety of ways for students to explore curriculum content, a wide selection of sense-making activities or processes through which students can come to understand and "own" information and ideas, and many options through which students can demonstrate or exhibit what they have learned (Tomlinson 1995; Haberman 1992; Senk and Thompson 2003). Consequentially, the PD sessions focused both on pedagogical issues and the mathematical content that the teachers were required to teach.

Our PD aimed at supporting school mathematics reform followed the research and recommendations of Borasi and Fonzi (2002), Loucks-Horsley, Stiles, and Hewson (1996) and Loucks-Horsley, Love, Stiles, Mundry, and Hewson (2003). Thus, the PD: 1) was driven by a clear, well-defined image of effective classroom learning and teaching, 2) provided teachers with opportunities to develop knowledge and skills and broaden their teaching approaches, so they could create better learning opportunities for students, 3) used instructional methods to promote learning for adults which mirrored the methods to be used with students, 3) built or strengthened the learning community of mathematics teachers, 4) prepared and supported teachers to serve in leadership roles if they were inclined to do so, 5) consciously provided links to other parts of the educational system, and 6) included continuous assessment (Loucks-Horsley, Stiles, and Hewson 1996). Schools applied to enter the TEAM-Math partnership. Acceptance was competitive, based on teacher commitment to involvement, administrative support, and a plan for a designated teacher leader to coordinate activities.

Teachers at schools accepted into the project attended a two-week summer institute, followed by a one-week follow-up institute, and half-day quarterly meetings on Saturday mornings throughout the school year. Other PD events were also offered. The project provided briefings and workshops for administrators during the summer institutes and on one-to-two occasions throughout the year. Teacher leaders in the project carry out four primary roles (Miller, 2003): change agent for individual teachers; change agent for groups of teachers, including professional learning communities (Wenger, 2000); vanguard for reform; and leadership intermediary. To support the growth of teacher leaders, the project provided quarterly half-day workshops to help them better understand their roles. Finally, teachers and teacher leaders were provided training on enhancing parental involvement during the summer institute and other events throughout the year.

Community and Parent Involvement. We used ideas from a number of sources that stressed the importance of working with and informing parents and other stakeholders about the advocated changes in the teaching and learning of mathematics in timely and productive ways (Meyer, Delagardelle, and Middleton 1996; Peressini 1998; Strutchens 2002; Hendrickson, Siebert, Smith, Kunzler, and Christensen 2004).

Overall, we have consistently tried to link research to practice in reciprocal ways. Our goals have been to base our work with project constituents on research related to systemic teacher change and to listen to the voices of the constituents as we make major decisions related to the project. A consistent theme throughout the partnership has been examining what has already been done through reviews of related literature and then determining what can be adapted for our situation. The primary elements—developing teacher leaders, providing reform based PD, and taking the needs of the constituents into consideration—were used in formulating the design and organization of the partnership.

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Describe, based on your expertise and knowledge of research, what would it take to design, implement, or assess quality of mathematics professional development that would support the implementation of the CCSSM content and practices

Professional development (PD) designed to support the implementation of the CCSSM should focus on three goals: 1) promote teacher understanding of the content goals from the perspective of learning trajectories and how students learn mathematics, 2) engage teachers in mathematical activities so that they value the Mathematical Practices emphasized in the CCSSM, and 3) develop teachers' classroom assessment conceptions and practices.

The development of the CCSSM content standards is based on contemporary research in student learning and related learning trajectories. This is particularly true for the content standards outlined for grades K-5. And yet, teachers nationwide have very little knowledge of these learning trajectories (LT) and how LTs could be used to inform planning, instructional decisions, and formative assessment. Content goals are often viewed as discrete, unrelated statements. Having teachers build a coherent portrait of the mathematical relationships articulated in the CCSSM is an important first step (i.e., within the targeted grade level and vertically articulated across grade levels).

Second, the statements of Mathematical Practices are a start. However, the way in which teachers within one school's mathematics department interpret a statement such as "Model with mathematics" can vary greatly. If teachers do not have an opportunity to engage in tasks that exemplify the Mathematical Practices for a given content domain and discuss the similarities and differences between these practices, they are less likely to value such activities and practices and effectively support their development with students. It is important that teachers develop an eye for distinctive features of these Mathematical Practices and how they are reflected in the tasks and related questions that they use with students.

With respect to assessment, six of the eight proposed mathematical practices require the use of activities and classroom methods that elicit student reasoning beyond simple recall of facts and procedures. For example, mathematical modeling, argumentation, and looking for/making use of structure are important goals that are often under addressed in teachers' assessment practices; the limited awareness of how to integrate such goals into classroom assessment influences the selection of activities, use of questions, and the manner of instruction.

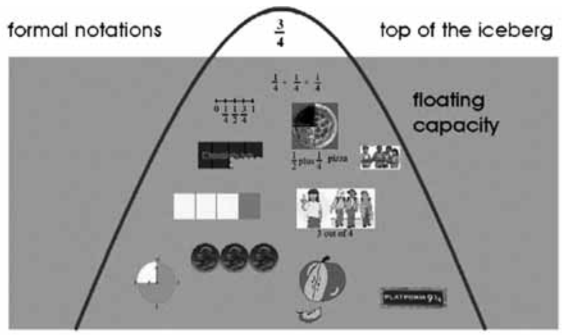
In recent discussions with practicing mathematics teachers, the majority identified PD addressing the design and use of classroom assessment as curiously non-existent in local PD offered by their district or local agencies, and yet they recognized this as one area of practice with which they could use the greatest assistance. Given the current accountability climate and the eventual shift to common assessments administered by PARCC and SMARTER consortia states, successive years will bring increased heightened interest to new methods of classroom assessment that are aligned with new large scale assessments. Prior to the release of assessments developed by the SMARTER and PARCC consortia in 2014, teachers need the opportunity to review and discuss how the goals outlined in the CCSSM are reflected in their classroom assessment practices and the assessments design by these consortia.

Facilitating change in teachers' practice is not so much a resource problem, as it is a problem of: a) creating opportunities for teachers to reconceptualize their instructional goals, b) re-evaluating the extent to which teachers' practices support those goals, and c) helping teachers develop a "designers' eye" for selecting, adapting and designing tasks to assess important goals.

Describe, in some detail, one idea you have for how professional development can be done at scale to support the implementation of the CCSSM.

One PD approach that can be accomplished at scale is to facilitate review of current instructional resources for grade-level content, the relationship between that content and bordering grade levels (i.e., exploration of potential learning trajectories), and mathematical practices as described in the CCSSM.

We have accomplished similar work with K-12 math teachers using the Iceberg Model (Webb, Boswinkel & Dekker, 2008) to collaboratively discuss the underlying contexts, representations and strategies related to particular grade level goals. The Iceberg Model is a visual metaphor that illustrates enacted features of progressive formalization through informal, pre-formal, and formal representations.



The iceberg consists of the "tip of the iceberg" and a much larger area underneath, designated the "floating capacity." The top of the iceberg represents the formal procedure or symbolic representation of interest. However, before this formal level is reached, students should have an opportunity to encounter informal contexts and pre-formal representations. These informal and pre-formal representations and strategies play an important role in understanding the formal mathematics. Students first encounter in realistic contexts, which motivate the use of mathematical language (e.g., three quarters of an hour, three quarters of a dollar, etc.). Later they use more structured pre-formal manipulatives or models (e.g., fraction bar, number line, etc.) which support student sense making and understanding of the formal notation (e.g., that three fourths is 1⁄4 + 1⁄4 + 1⁄4).

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One big challenge in advancing the CCSSM is for teachers, administrators, parents, and the general public to have an understanding of what the CCSSM is proclaiming about what students should know and when they should have this knowledge. As a new document, people need to know how the implementation of the CCSSM will benefit students, their lives, and our country.

A series of documents need to be prepared to help teachers grasp what is in the CCSSM, how these expectations are the same and different from the status quo, and how does each grade and course fit within the larger context. The CCSSM document contains a great deal of information, but requires significant work to gain a full sense of the standards. At a minimum, the CCSSM domains need to be mapped across grades in a reasonable configuration such as using a matrix. This depiction should show within a domain the major topics and how these topics mapped within and across grades. These mappings should make it clear when a student is expected to be proficient in a topic. Another set of mappings need to provide suggestive sequences that indicate when a topic should be introduced and how a set of topics for a grade level could be sequenced.

Scaffolding materials such as these mappings are essential for teachers and others to have some awareness of what the CCSSM are advancing and why the CCSSM should replace the existing standards. Dan Heck's model of professional growth provides one of the most succinct depictions of what is important for teachers to change (Webb, Heck, & Tate, 1996, p.321). In his model, there are seven elements of professional growth—disequilibrium, exposure, existence proof, experimentation, reflection, support, and modeling). These elements were identified from interviewing a number of teachers who were engaged in changing their practices as participants in the Urban Mathematics Collaborative Project in the latter 1980s and 1990s. The disequilibrium element was found to be very critical in the change process. Teachers need to have some dissatisfaction with what they are doing and what their students are learning in order to entertain any reform or revise their curriculum. Without some disequilibrium, teachers are very cautious and reluctant to change what they believe has served their students very well. Before teachers will be willing to devote the effort that will be required to decipher the CCSSM, they need to have some dissatisfaction with the current state standards and curriculum. Part of creating disequilibrium with the status quo is for teachers to have an awareness that the CCSSM present an approach to learning mathematics that will serve their students better than the existing standards. This will come, in part, from teachers having some awareness of what the CCSSM is advancing, what its structure is, how it is different, and what are its benefits. Scaffolding materials are critical for this step.

Scaffolding materials on the CCSSM should be general enough that they could be prepared by some central agency or group and be disseminated among all of the states. It is not necessary for these materials to be state specific.

Next, teachers need to have more exposure to the CCSSM and have examples of how using the CCSSM will benefit students. The scaffolding materials noted above will help to provide teachers with some exposure, but still teachers will need to have more details on what they need to do with their own grades or courses. The standards are written with rigor in mind, but not necessarily teacher consumption. For a grade level teacher, the standards will need to be unpacked or broken apart to be sure that she/he is aware of all that is expected of students for the grade. Small group discussions among teachers about the standards for a grade are one way for teachers to be exposed to the CCSSM. However, such discussions need to have some mechanism to assure that teachers are correctly interpreting the standards. Along with being exposed to the standards, teachers need some evidence that the CCSSM are good and will benefit their students. Because the CCSSM are new, no one has used them so there is no direct evidence of the standards' worth. Somebody needs to produce some analyses that will serve as initial existence proofs for the CCSSM. Such materials could be results from alignment studies of the CCSSM with standards from high-performing countries (e.g. Finland, Singapore), results from alignment studies of the CCSSM with high-performing states, and achievement of students from schools or districts whose curriculum may already be nearly aligned with the CCSSM students. A critical part of finding existence proofs for the CCSSM is to have evidence that what is being advocated will work for all students, including underrepresented students and low performing students. Efforts should already be in place to produce existence proofs for the CCSSM.

Once teachers have some agreement that the CCSSM are good for their students and are aware of the general aspects of the standards, then teachers need to work on implementing the standards in their classrooms. In this phase of PD, teachers need modeling of teaching the standards at their grade level or course. Part of this modeling needs to break down the wording of the specific standards so that teachers fully understand the mathematics in the standards and a progression in learning over the year or course. Setting priorities for the year need to be demonstrated. Teachers need help in deciding what the most important content standards are for the year, and how instruction can have students attained these expectations. Some of the modeling should be on assessment. Teachers will need insights into what evidence is needed to show students are making progress towards reaching the standards.

Along with modeling, teachers also need to experiment in their own classrooms with instruction aligned with the standards. Such experimentation is needed for teachers to see what is required for their own students to meet the full expectations of the standards. Modeling and experimentation imply an iterative model of PD. An iterative approach would have a session that would model a set of lessons and then time for teachers to try what they observed in their own classes. Then a session and time for experimentation would be repeated. Of course, ideally each teacher would have his or her own mentor to model and debrief what they are doing. But with current technology, some form of a Webinar or remote large-scale modeling with some mechanism to respond to individual teachers' question may work.

Finally, teachers need support from other teachers and the administration for implementing the CCSSM and time to reflect on their practices. This implies that principals, administrators, and school board members need to be versant in the CCSSM and what is needed for teachers to successfully implement these expectations with their students. PD needs to be provided and required of the administrators with information on what it will take for teachers to make the change. This may require administrators to give teachers more freedom to experiment and not attain all that is expected within a year. Without adequate support, it is unlikely teachers will do what is necessary to implement the new expectations. Along with receiving appropriate support, teachers will need time and engagement with other teachers to reflect on the progress they are making in fully implementing the CCSSM. This will require finding time during the school week for teachers to go over what they have done, how this compares to what is needed to be done, and what changes they need to make.

Much of what is discussed here are just good practices for PD for any new initiative. There are many books, such as the one written by Susan Louks-Horsley and others (2010), that provide sound PD practices that will apply to implementing the CCSSM. However, there are some characteristics of the CCSSM that should receive special attention. Some of these are the use of more formal mathematical language, more concentration of topics requiring a shorter time from introduction to proficiency, and using learning progressions in teaching.

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The CCSSM provide PreK-12 mathematics teachers, mathematics educators and researchers, mathematicians, and mathematics professional developers with several opportunities and challenges. They are an opportunity to renew, revise, and transition into an improved field of mathematics teaching and learning (Beckmann, 2011). Yet, one major challenge for implementation of the CCSSM will be aligning teacher preparation to the standards and developing curriculum materials and assessments (Center on Education Policy, 2011). Therefore, teachers will need professional development (PD) to implement the CCSSM.

The PD should have a clear plan for engaging teachers in both mathematics content and mathematical practices, be sustained, and help teachers learn how to reflect on their practice. Too often, PD efforts only provide teachers with the way the mathematics is presented in the document. Little attention is given to the practices and how they will require teachers to think and act differently in the classroom. Alignment should include what to teach, how, and why. It should focus on mathematics content and help teachers develop content knowledge so that they can better predict and analyze their students' thinking. This focus on content would include understanding the curriculum, or in this case, CCSSM.

Hirsch and Reys (2009) suggest, "To be effective, curriculum standards must be translated into materials that guide the day-to-day decisions of teachers and help them focus on the important mathematical learning goals in significant ways" (p. 753). Because many states already have some form of curriculum standards in place, there will have to be some time spent helping teachers understand how CCSSM aligns with their current set of standards. Expectations for students across grades K-12 should be understood so that teachers can see how the content in each grade level has changed. In addition to understanding how the standards align, teachers need time to understand the language of the CCSSM, since it may be different than what they are currently used to. More specifically, components of alignment must include language and vocabulary.

Other aspects of mathematical knowledge that will be important for teachers to understand in order for them to implement the CCSSM are classroom discourse and multiple representations. These are highlighted in NCTM, so they may already be a part of PD in states. But teachers need time to explore and learn how to facilitate classroom discourse focused on problem solving. They also need to spend time developing their knowledge of connections across representations and across content.

As with all new curriculum initiatives, I am concerned about equity issues, and whether all students will have full access to the mathematics in the CCSSM (Gutstein, 2010). Some indicators of negative effects of the CCSSM would be that mathematics achievement gaps across race and socioeconomic status remain the same or widen, and teachers in urban and rural schools are not prepared to implement the standards with fidelity. Therefore, equity-related concerns must be part of the initial design of any PD. As we provide teachers with PD, we must attend to the various ways student engage in mathematics, the institutional structures that either support or hinder students' engagement in mathematics, and how students experience mathematics both within and outside the classroom. This can occur when professional developers engage teachers in conversations that are relevant to their schools and districts.

One idea for how PD can be done at scale (i.e., with a whole district or an entire state) to support the implementation of the CCSSM is through teacher leader/coach institutes. These leaders can reach groups of teachers in their respective schools and districts. However, they must have a strong foundation in the vision and goals of the CCSSM. Teacher leaders/coaches must understand how teachers learn and what motivates them to consider a different way of teaching. Alignment of the CCSSM for the selection of coaches would mean that districts select individuals who: are knowledgeable in the mathematics presented in the standards, have experience teaching mathematics, and have a clear understanding of current state standards. Their preparation should include PD on the alignment of the CCSSM with current state standards, the mathematical practices, and issues of equity and state/local testing. Supporting the coaches requires that districts have a clear plan to deliver PD on the CCSSM over the school year, opportunities for coaches to get together to share their strategies for teaching teachers, and means of assessing whether and how coaches are influencing teaching and student learning. For example, professional developers will need to help the coaches support each other's understanding of the standards for mathematical practices by engaging in "extended study, learning, and discussion within a professional learning community focused on how to help students become mathematically proficient" (Seely, 2011). Once coaches have this understanding, they should devise plans to communicate this information with teachers and administrators.

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Before sharing ideas relative to the topics requested, I feel it is useful to describe the perspective from which I approach my work in mathematics education. For seven years, I have served as the mathematics consultant for Stow-Munroe Falls City Schools, which is a suburban district of about 5,800 students just north of Akron, Ohio. We have seven elementary schools, one middle school, and one high school. I work both with teachers in inservice settings and (for about half of each day) with students and teachers in classrooms, as well as coordinating the mathematics program in our district. Before I entered this position, I taught middle school mathematics for six years, and I have worked with an Ohio professor on NSF-funded projects related to the assessment of children's mathematical understanding and the professional learning of teachers that is necessary to support children's mathematical development. Further, I am a doctoral candidate in Curriculum and Instruction with a focus in mathematics education, and I am concluding a term as Past President of the Ohio Council of Teachers of Mathematics. As president, I was fortunate to work with educators and leaders from across Ohio to support and develop quality professional learning opportunities for teachers in K-12.

We have been asked to consider what it would take to design and implement quality professional development (PD) to support implementation of the content and practices that appear in the CCSSM. Typically, I approach this type of question from a practitioner's perspective that is informed by research grounded in constructivism. Individually described (briefly) below are the factors that, in my experience, most positively influence the design and implementation of such professional learning opportunities (note that I use the word "learning" as opposed to "development" because I feel that "learning" places the focus on *what the educator does* as opposed to *what someone else does to the educator*).

Time – Ongoing, regular time must be provided for educators to learn, reflect, and collaborate.

Collaboration – Educators can learn much from each other. In a dynamic professional environment, most expertise can and should come from within, rather than from external sources.

Involved, supportive leaders – Principals and district administrators who clearly demonstrate, through actions and words, that ongoing professional learning is worthwhile and important (for themselves as well as teachers) set high expectations for all educators who work in the school or district, as well as helping to establish a culture for this learning.

A coherent yet organic set of beliefs about student learning in mathematics and teaching that supports learning – Since professional learning guides the practices that support students in learning, we must be very clear about what and how we wish students to learn in mathematics (thus, how we must teach). We must also be willing to allow these beliefs to evolve over time as common understandings within a school culture evolve and professional wisdom grows.

Reasonable short-term and long-term goals for each phase of professional learning – Educators should know what is expected and when so that they do not become overwhelmed with trying to change too much too quickly (or too slowly).

The use of research literature to inform, though not to initiate, professional learning – Virtually all educators are interested in ways to improve their students' learning. Drawing on this interest provides an opportunity for using research literature that is presented in a way that resonates with educators' classroom experiences. However, PD that is based on research that educators perceive as unconnected with their experience will generally have little effect on educators' reflection or practice.

An emphasis on practices that tend to be effective in essentially all classrooms and lessons – It is very helpful to establish a set of general (non-prescriptive) practices that are common to all grade levels. This helps educators to feel that they are part of a larger system of teaching and learning, and it also is useful in reflecting on new questions about practice that arise.

A well-placed emphasis on instructional strategies that are effective for the teaching and learning of specific ideas, as well as on student learning trajectories in these areas – Of course, educators benefit from learning about ways to develop specific ideas with students.

The opportunity for each educator to identify personal goals for professional learning and improvement, and contribute to collective goals – Leaders must recognize that different educators have different needs for professional learning, just as students have different needs. Asking educators to consider what their "big questions" are, and then supporting them in seeking insights into these questions, helps educators to develop a habit of inquiring about teaching and learning throughout their careers, and to feel that their questions are important.

Meeting the most basic needs of teachers as professional learning continues – Teachers must feel that their needs for tangible (and other) resources are relatively well met in order to be able to feel that professional learning opportunities can truly help them to improve their practice.

We have also been asked to describe one idea for scaling up professional learning. The example below is based on experiences that we have been able to provide in Stow-Munroe Falls during the last few years.

A successful PD structure provides common learning experiences for all educators in a school community, as well as additional experiences for those who wish to deepen their learning and perhaps become leaders among their colleagues. A district would be especially fortunate to have a mathematics curriculum leader to organize these activities; ideally, every district should have such a leader. With the advent of the CCSSM, a district could provide three half-days of learning opportunities throughout the year by grade level in which teachers could: 1) start to become familiar with the standards, 2) compare/contrast them with current standards, 3) establish a commonly understood vision for student learning based on the CCSSM and other research on student thinking, and 4) create, and later discuss the results of, common assessments. Each month (or, much better, each week), educators could meet in smaller teams for an hour to continue to collaboratively reflect on their increasing enactment of the new standards. Further, the district could create a group of educators across a district who were all interested in deep reflection on the teaching and learning of mathematics. These educators would identify their own "big questions" and meet in inservices starting in August and once each month during the year, sometimes in inservices and sometimes after school. Over a period of several years, veteran members of this group would become leaders in their own schools and would support collaboration among colleagues and the promotion of new structures and strategies for supporting student learning.

If a district did not have a mathematics curriculum leader to organize these activities, district administrators would need to find effective local leaders to catalyze this work and work with interested educators in the district who could eventually become leaders themselves. Above all, however, the design, continual planning, and evaluation of these efforts should involve teachers as central players, with administrators actively supporting the ongoing work.

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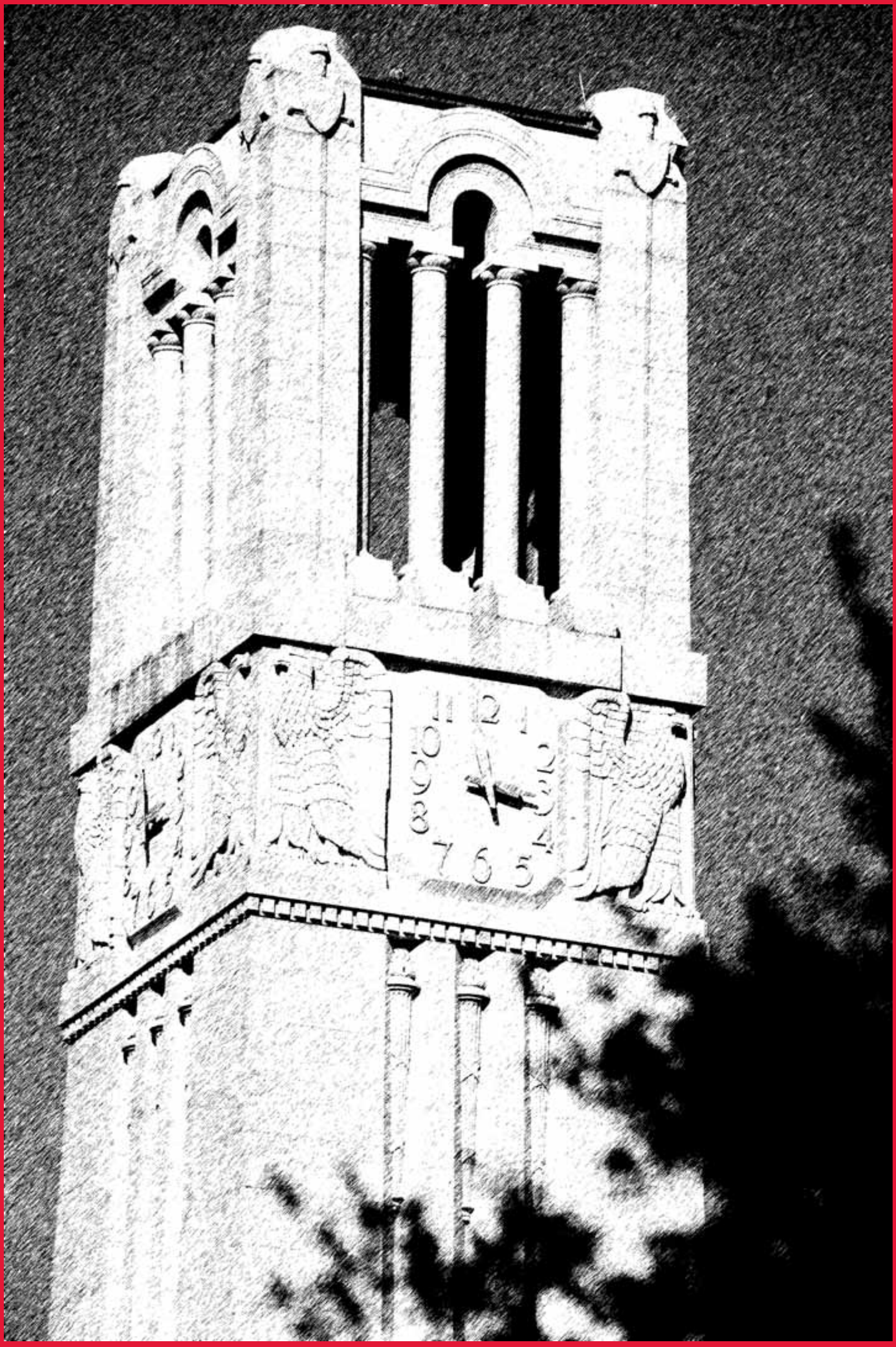

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