Center for the Study of Mathematics Curriculum

Curriculum Design, Development, and Implementation in an Era of Common Core State Standards

Summary Report of a Conference

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Preface

In June 2010, the National Governor's Association and the Council of Chief State School Officers published *Common Core State Standards* (CCSS) for K–12 mathematics. Forty-eight states collaborated in the development of CCSS and, to date, 34 states have officially adopted CCSS to replace existing state standards. CCSS presents an opportunity for critical stakeholders to focus on curriculum as a means of improving teaching and student learning.

In order to help state and local school systems design thoughtful curriculum guides and select instructional materials (text, e-text, and ancillaries) that are essential supports for implementation of the CCSS, it is necessary to connect those who have constructed the *Common Core State Standards* in mathematics with those members of the educational community who are expert in designing, developing, and implementing mathematics curriculum resources and instructional programs. Collaborations across these communities will help identify the work that needs to be done to provide strong resources for the field in the future.

Therefore, a meeting of key stakeholders was convened August 1–3, 2010 to discuss curriculum-related work needed in response to the *Common Core State Standards for Mathematics*. The goals of the meeting were to: (a) provide guidance on future mathematics materials development efforts, K–12, and (b) address issues of curriculum design and production that arise in an environment of Common Core State Standards. Key questions considered included:

- What are the most important implications of the new national curriculum guidelines for change in traditional scope and sequence of school mathematics?
- How well will existing curriculum resources support curricula that meet the new guidelines?
- What curriculum development and research activity is most important in supporting longer-term successful implementation of the CCSS?
- What innovative curriculum development and research should be undertaken to prepare for informed revision of the national standards in the future, as mathematics education adapts to what is certain to be rapidly changing conditions and expectations for STEM education and education in general?

This report serves as a public dissemination of conference discussions, recommendations, and items for action.

Chris Hirsch, Chair, Conference Organizing Committee

A Summary Report from the Conference "Curriculum Design, Development, and Implementation in an Era of Common Core State Standards"

Jere Confrey and Erin Krupa, North Carolina State University

> *Rushing through things often results in the opposite of what you really want to do and ends up creating more work, not less. Hurrying through a job can be counterproductive.* Chinese proverb

The release of the *Common Core State Standards*[1] (CCSS) opens the door to a variety of opportunities and challenges. As of the conference dates, the adoption of the CCSS by 34 states signals widespread support for implementation of economies of scale in pursuit of more effective mathematics teaching and learning. A number of critical elements are coalescing to change the face of K–12 mathematics education in the U.S. These elements include the broad level of state support for the CCSS and collaboration among states in developing new, common forms of assessment. Also shared is a common goal of bringing greater focus and coherence to K–12 mathematics, an emphasis on mathematical practices, and attention to developing understanding of concepts and skills. While development of the CCSS and widespread adoption is an accomplishment, in fact its passage marks only the beginning of the work to be done through professional development, creation of instructional materials and related tools, and phased implementation. As states are already moving vigorously—sometimes precipitously—towards implementation in the wake of the CCSS adoption, there is a perception of urgency as well as the need for deliberate and informed planning. The planning must draw on lessons already learned in the process of standards-based school improvement from the last two rounds of NCTM Standards in 1989 and 2000 (Goertz, 2010).

Furthermore, the time period from now (summer 2010) until 2014—the target date for the coalitions of states and experts to produce new assessments affiliated with the CCSS—represents a critical transition period, replete with the combined opportunities and responsibilities to define the meaning of the CCSS in relation to classroom practices on a large scale. Not only is it important to leverage the circumstance occasioned by the passage of the CCSS, but also to be certain that its implementation supports and reinforces the progress made to date. For the first time, many states can engage jointly in the heavy lifting of real change. To coordinate these efforts, we must identify and act on immediate tasks while we simultaneously undertake long-term targets necessary to ensure the creation and implementation of higher quality and highly effective mathematics curriculum, instruction, and learning, and to ensure that these transformations are sustained for many years.

In order to advise the nation, an expert group[2] of designers and publishers of mathematics curriculum materials in the U.S., along with front-line implementers from states and large school districts who are experienced in facilitating and managing school improvement

[1] See http://www.corestandards.org/ for a copy of the document.
[2] See list of conference participants on pages 22–23.

and policy experts from major funding organizations in Washington D.C., convened to produce a set of recommendations and action steps for the deliberate and productive implementation, maintenance, and extended support of the CCSS. The group began with a shared fundamental assumption: *Curricula matter!* Based on this assumption, the group focused on the implications of the widespread adoption of the CCSS for mathematics curriculum-related activities and materials.

Structure and Organization of the Meeting

The meeting consisted of three plenary talks, two panels, and three sessions of working groups. On the final day, summary presentations of recommendations were given by each of the working groups.

Dr. Phil Daro, one of the writers of the CCSS, delivered the opening plenary. He described the goal of the standards as answering the question, "What is the math I want students to walk away with?" He identified some of the key assumptions held by the writers, including the view that (a) the CCSS were written to assume 100% mastery, in any given year, of the preceding year's standards; (b) standards are high points, not finish lines or curriculum; and (c) the grain size for effective change should be at the chapter or unit rather than at the lesson level. He reviewed the objectives in writing the standards: they were to be "higher, clearer, and fewer," "benchmarked to those of high-performing countries," "oriented to college and career readiness," and "evidence-based." Daro emphasized the importance of mathematical practices[3] as a foundation across the K–12 standards, the focus on understanding core concepts, and the importance of fluency with core skills. He also provided insight into the writers' thinking and how they made some of their decisions. He concluded by pointing to areas where additional work is needed to inform future adaptations of CCSS, such as outlining learning progressions and examining more clearly the role and influence of technology in learning and doing mathematics.

In the second plenary talk, Dr. Jere Confrey began by emphasizing that the CCSS were "good enough" for the mathematics education community to rally behind due to the potential benefits of consolidating efforts across the states and supporting a more unified experience for all students, especially those who move from school to school throughout their K–12 experience. She outlined the strengths of the CCSS as well as areas in need of improvement:

<u>Strengths</u>

- They focus attention on core concepts in number and numeration and their relationships to operations, with particular focus on the structure of the number system.
- They develop place value in a coordinated and informed way across the grades.
- They tie decimal reasoning strongly to fractions.

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[3] The *Standards for Mathematical Practice* describe varieties of expertise that mathematics educators at all levels should seek to develop in their students. They are outlined on pages 6–9 of the CCSS document.

- They introduce multiple measurement systems (metric, non-standard, and English) simultaneously and tie the number line directly to scales to improve students' visualization of some number relationships.
- They are more aggressive in their timelines for teaching particular concepts in elementary and middle grades mathematics, such as establishing basic algebraic proficiency as a universal objective for all students by eighth grade.
- They develop more explicit exploration of geometric relationships in middle school to prepare students for formalization of those concepts at high school.
- They support the articulation of some key learning trajectories in numeration and in geometry.
- They do not outline a particular course sequence/organization for high school mathematics, recognizing that different pathways are viable for enabling students to attain the goals of CCSS.

<u>Areas in Need of Further Consideration or Revision</u>

- The mathematical practices are presented independent of the content standards, thereby risking that the practices are isolated and under-emphasized.
- While modeling is listed as both a mathematical practice and a conceptual category, the standards associated with modeling give inadequate attention to the development of the practices, skills, and technologies essential to proficiency in modeling, and instead treat modeling as mostly an issue of application.
- Throughout the standards, only limited attention is given to the role of technologies and their impact on twenty-first century perspectives on computational tools and simulations.
- They ignore significant empirical data on children's ability to develop an understanding of variability, distributions, data use, statistical reasoning, and probability in the early grades; instead, these are added abruptly in sixth and seventh grade.
- They place a particularly heavy burden on the capacity of middle school teachers during the age range when we witness significant drops in student performance on NAEP.
- The concept of number is narrowly built, over-relying on additive structures, thus constraining the early and foundational development of multiplicative structures related to ratio, rate, and many algebraic patterns of growth.
- Especially at the high school level, the grain size of the standards varies widely and there is a need to further unpack standards of large grain size in order to advise how the sub-constructs develop and build on each other.
- The wording of the standards is, in some cases, obtuse, combining statements that read like mathematics propositions with combinations of content and pedagogical advice. In other cases, the verbs used are difficult to readily link to assessments.
- How the standards address "career readiness" and its relationship to "college readiness" is not clarified.

Confrey stressed the importance of drawing on the statement in the CCSS that emphasizes the importance of understanding. A lack of understanding may cause students to be "less likely to consider analogous problems, represent problems coherently, justify conclusions, apply the mathematics to practical situations, use technology mindfully to work with the mathematics, explain the mathematics accurately to other students, step back for an overview, or deviate from a known procedure to find a shortcut" (CCSS, 2010, p. 8). She also acknowledged that the standards that begin with "understanding" provide particularly compelling opportunities for linking the eight mathematical practices to related content standards.

Confrey proposed five strategies as priorities in implementing the CCSS:

1. Phasing the implementation of the CCSS in a planned, purposeful, and coordinated way;
2. Articulating and expanding the underlying learning trajectories in the CCSS to guide assessment;
3. Re-visioning the relationship among the CCSS, curriculum materials, and classroom assessment to drive engagement, customization, and reach;
4. Appropriating the 15% of a state's standards that do not have to comply with the CCSS and use it to define and deploy a broader college and career STEM agenda; and
5. Using longitudinal data systems to decipher and study curricular effectiveness as understood by the curriculum development and research community.

The third plenary was delivered by Dr. Hugh Burkhardt on "Assessment Tools for Implementing the Standards." His message to the group focused on the need to ensure that the CCSS are assessed in ways that promote, rather than inhibit, deep learning. He characterized this work as engineering design challenges. He reported on current progress of an assessment project designed to provide "open source" exemplars of rich tools used for formative assessment. He outlined ways in which rich tasks can elicit a deeper exposure of student ideas and placed these into instructional routines designed to encourage a combination of individual activity and group discussions. The tasks included novice tasks eliciting elementary beliefs and conceptions, apprentice tasks with scaffolded "ramps of difficulty," and expert tasks for those who can solve problems as they arise.

The conference also included two plenary panels. The first panel (Linda Davenport, Brad Findell, David Foster, and Diane Schaefer) described current initiatives to implement the CCSS in the context of ongoing practice. These presentations provided sources for later discussions in the working groups and had significant impact on the recommendations that were made. For example, Davenport, Mathematics Director for Boston Public Schools, described how she is focusing on the implementation of the mathematical practices with teachers in her district. She described the need to then gradually shift to the designated grade-level content standards; ensure that teachers reach all students, including special populations; and help teachers, parents, and administrators understand the CCSS. Schaefer, a former mathematics supervisor for Rhode Island, also reminded participants of the differences in attention among state-level educators' (who focus on overall systemic alignment), district-level administrators' (who focus on curricular alignment), teachers' (who focus on standards-oriented instruction), and other stakeholders' needs. Findell, President of the Association of State Supervisors of

Mathematics, outlined a variety of implementation timelines: short-term awareness, medium-term, capacity building, and long-term involving new digital tools and curricula. Foster, Executive Director of the Silicon Valley Mathematics Initiative, and Findell both emphasized the need to ensure that the CCSS be taught to a considerable depth of knowledge (Webb, 1997) and that coherence and quality be ensured through using proven professional development principles (focusing on content, drawing on curricular materials, analyzing student work, and utilizing a long-term approach to professional development). Multiple presenters discussed the potential value of using learning trajectories to describe the development of content over time, and several identified critical issues, such as early acceleration of students into high school mathematics at eighth grade; local control; limited resources; other competing initiatives; and a tendency to misuse professional development funds for generic, rather than targeted, uses.

The second panel consisted of senior program officers from NSF, Janice Earle and Michael Haney, and a Special Assistant to the Secretary of Education, Michael Lach. During the panel, Earle described the CCSS as a "living document, which should be poked, prodded, examined, and studied." She outlined potential topics of study, including identification of gaps in the empirical base for the underlying learning trajectories, the impact that the implementation of the CCSS has on low-performing students, level of support for implementation needs, and the role of technology. Haney called for "even bolder moves" and identified additional studies around the CCSS focusing on how to strengthen student engagement, share teaching practices, and conceptualize the next generation of curricula, tools, and technologies.

Lach reviewed four assurances as areas of focus for the Department of Education: (1) making progress toward rigorous college- and career-ready standards and high-quality assessments that are valid and reliable for all students, including English language learners and students with disabilities; (2) establishing pre-K to college and career data systems that track progress and foster continuous improvement; (3) making improvements in teacher effectiveness and in the equitable distribution of qualified teachers for all students, particularly students who are most in need; and (4) providing intensive support and effective interventions for the lowest performing schools (U. S. Department of Education, 2009, p. 5). He argued that the community should learn from previous attempts to implement standards, where there was not enough investment in professional development. He further challenged the audience to consider "new business models" for professional development, assessments, and supports for implementation.

The remainder of the meeting consisted of working groups in which numerous participants contributed to proposing, consolidating, and submitting recommendations about curriculum design, development, and implementation in the context of the CCSS. The recommendations and action items offered below were informed by the discussions and recommendations shared in the working groups.

Frameworks

Two frameworks are relevant to implementation of the CCSS and serve as a means to organize the group's recommendations. Figure 1 provides a framework from *Investigating the Influence of Standards: A Framework for Research in Mathematics, Science, and Technology Education* (National Research Council, 2002a). This framework provides a comprehensive display of the factors influencing the implementation of standards. It served to remind the participants of the breadth of forces and channels that need to be examined in order to achieve the desired impact on student learning.

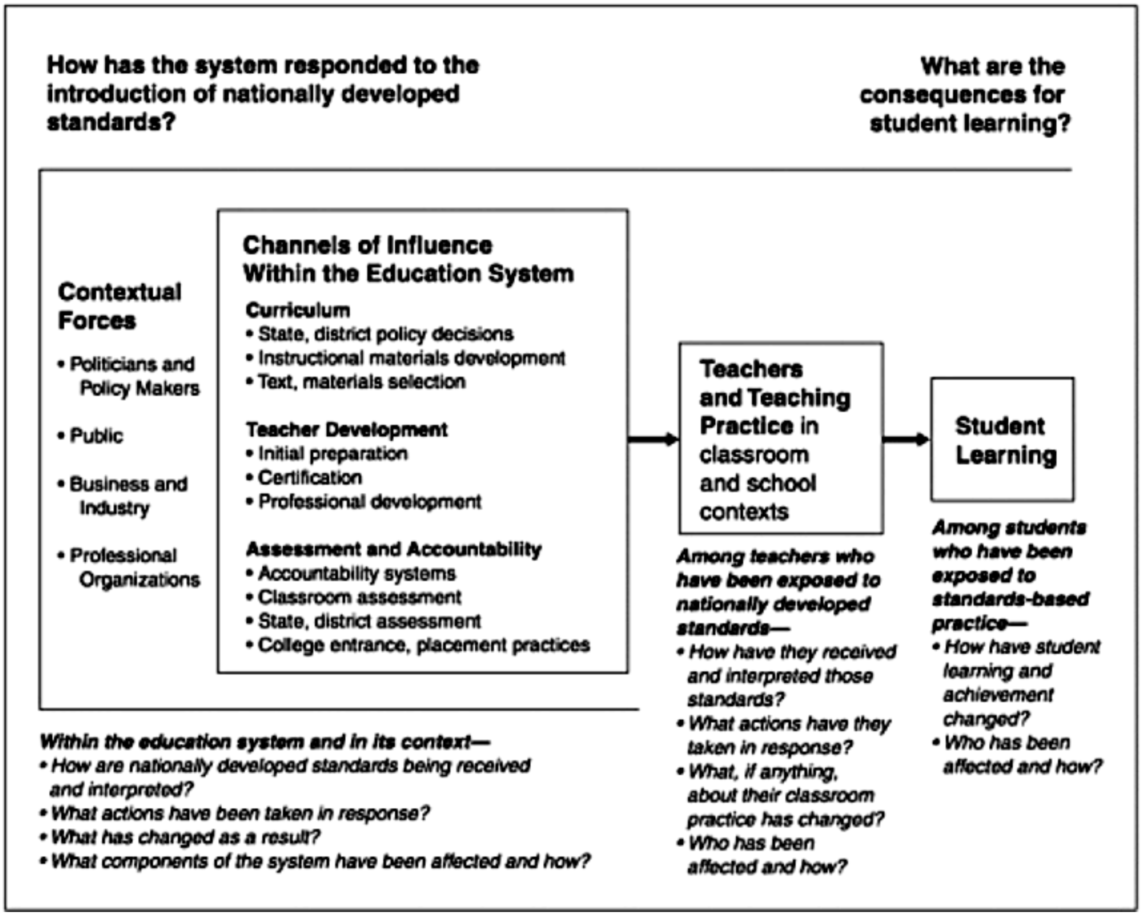

Figure 1: *Investigating the Influence of Standards: A Framework for Research in Mathematics, Science, and Technology Education* (NRC, 2002a).

Another framework (Figure 2) was presented during the second plenary of the conference. This framework presents standards and high stakes tests as the bookends of the instructional process. They are connected to show that the data from the high stakes exams are/were meant to inform both instructional practice and the development of the standards. The second framework complements the first with its focus on the effects of the CCSS on classroom practice in order to effect student outcomes.

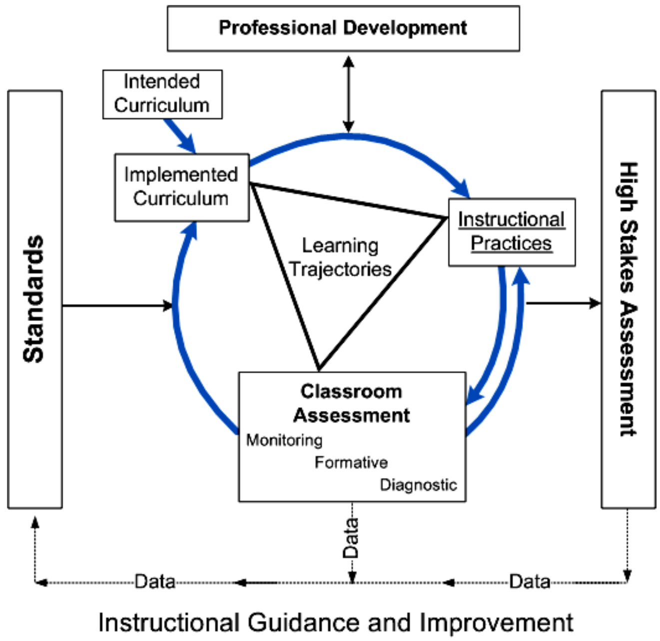

Figure 2: *Embedding the Instructional Core in an Accountability Framework (Confrey & Maloney, in press).*

In Figure 2, the triangle indicates that effective classroom practice, the heart of quality instruction, operates by the interactions among the enacted curriculum, instructional practices, and forms of classroom assessment. The double arrow to professional development signals that fostering rich classroom practices is enhanced when professional development is provided for teachers and when the "best practices" of experienced teachers, along with research, inform the professional development. The purpose of including this framework was to focus attention on what needs to happen in the classroom in relation to curriculum, instruction, and assessment to effect improvements in student learning.

Improvements in learning depend on the optimal combination of: (1) targeting essential content, (2) promoting the active engagement of students with compelling curricular materials, (3) building effective interactive and responsive instructional practices, and (4) utilizing feedback from students' thinking and their cognitive development. These four factors are essential to the successful implementation of CCSS.

What follows are recommendations based on conference discussions.

Conference Recommendations

The remaining portion of this document is organized in eight sections:

1. UTILIZING THE CCSS AS A LIVING DOCUMENT
2. SIGNIFICANCE OF THE MATHEMATICAL PRACTICES IN THE CCSS
3. IMPLEMENTATION OF THE CCSS AND ASSOCIATED TOOL DEVELOPMENT
4. NEXT STEPS IN CURRICULUM DEVELOPMENT AND TECHNOLOGY
5. IMPLICATIONS OF THE CCSS FOR ASSESSMENT PRACTICES
6. PROFESSIONAL DEVELOPMENT
7. CONDUCT OF RESEARCH ON CURRICULA AND IN SUPPORT OF NEW CURRICULA
8. POLICY AND ORGANIZATION

Each section includes one or more recommendations, followed by a discussion of key issues raised by conference participants, and action steps associated with the recommendation.

SECTION ONE. UTILIZING THE CCSS AS A LIVING DOCUMENT

Recommendation 1: Ensure that the Standards are a living document.

Discussion: The participants reported frustration with the lack of transparency in the development process for the CCSS, including the lack of public documentation of the decisions reached to add or eliminate content. Some participants identified particular standards in which the language is ambiguous or awkward or where the standard read more like an activity than a learning goal. Other participants felt that some of the weaknesses and omissions outlined previously should be remediated immediately. This led to recommending the development of a transparent process, much like that of the NRC—a process based on evidence, open to debate and discussion, and dedicated to improvement of the Standards over short, medium, and longer time spans.

Action Items:

A. *Create a process to support short-term fixes, medium-term adjustments, and long-term review and modification, as needed, based on expert advice and empirical evidence, and insulate this process from excessive political influence.*

B. *Increase the transparency of the Standards improvement process and ensure the involvement of the entire mathematics education community, including teachers, special educators, mathematics education researchers and curriculum developers, mathematicians, and assessment specialists.*

Recommendation 2: Recognize the imperative to help teachers and schools interpret the Standards.

Discussion: Mechanisms must be designed to respond to questions related to clarification and interpretation of the CCSS. Part of building awareness of the Standards should be assistance for interpreting the Standards and the development of more clarifying examples.

Action Item:

A. *Build a public site, maintained by an expert panel, to assist in the interpretation of the meaning of the Standards with associated examples beyond those currently contained in the document.*

SECTION TWO. SIGNIFICANCE OF THE MATHEMATICAL PRACTICES IN THE CCSS

Recommendation 3: Lead with the mathematical practices.

Discussion: For students to become proficient in mathematics, they must internalize the eight mathematical practices as the means to learn and understand the content standards. The practices sustain mathematics as the content evolves. As such, they make what students learn enduring and they ensure that students will continue to be prepared to learn new mathematics.

Action Items:

A. *Begin implementing the CCSS with the mathematical practices.*

B. *Revise current curriculum materials/resources to make the connections to the practices more explicit.*

C. *Ensure that all new assessments evaluate students' proficiency in the practices with connections among the content standards.*

D. *Develop a practice-based observational scheme for principals to use in conducting classroom evaluations that focus on the development of mathematical practices.*

Section Three. Implementation of the CCSS and Associated Tool Development

Recommendation 4: Consider methods to phase in the Standards.

Discussion: In recognition that the CCSS includes significant modification of topics to be taught at a given grade level, compared to the majority of current state standards, we recommend a phased approach to implementation. It should start with awareness (teachers, administrators, and parents) and then proceed toward providing teachers with specific guidance regarding the expectations of use. It is unreasonable to expect a system to change uniformly to new standards without considering that students will enter many grades without the expected prerequisites; to pretend to do so simply increases the cynicism that these standards too will be ephemeral, soon to be replaced with some new trend. Instead, implementation of these Standards requires extensive coordinated planning. It is also imperative to consider how to plan periodic events such as adoption cycles. These should take into account guidelines in the Elementary and Secondary Education Act (ESEA), as they emerge, with a focus on grade transitions.

For example, the Standards might be phased in by year (grades K–2 in 2011, grades 3–5 in 2012, grades 6–8 in 2013, with a separate structure for high school by conceptual clusters).

Action Items:

A. *Create and share phasing plans.*

Recommendation 5: Provide all stakeholders adequate opportunities to learn about the CCSS. Key stakeholders include district-level administrators, principals, coaches, teachers, parents, university faculty in mathematics and mathematics education, external professional development providers, and students.

Discussion: As shown in the framework on the Influence of Standards (Figure 1), a broad community must be educated about the substance and implications of the CCSS. Implementation of the CCSS will necessarily involve responding to questions in more than an administrative way. Just as districts currently call upon state personnel to clarify what various standards mean or how they will be assessed, similar questions will now be raised by state personnel, curriculum developers, and assessment developers. An immediate need to support successful implementation is formation of a “board” that can answer such questions. The fact that this is new territory even to the Standards developers almost certainly means that the board should function not so much as a supreme court or information source, but by *coordinating* the knowledge of:

- CCSS developers—to clarify, where necessary, the *intent* of the standards that are given, the breadth and limits of those standards, and what might constitute sufficient evidence that a standard has been met;

- curriculum and assessment developers—to inform each other's work and to help answer states' questions about *how* the Standards might influence practice and appear in assessments;
- mathematics educators and mathematicians (and possibly other specialists, e.g., experts in cognitive science)—to assure that, as the details are worked out, *mathematical fidelity* (and, e.g., current understanding of cognition) is preserved;
- states and district personnel and teachers—for the purpose of *processing and preserving* their input, both to streamline and improve the implementation process of the CCSS and to provide a foundation for future evolution of the Standards.

This will require building an appropriate infrastructure that includes a central organization (a set of people to support the collaboration) and securing financial support to cover the time and effort of the collaborators. It may involve periodic meetings among collaborators, focused on particular questions from the field or on attempts to implement the CCSS. At the least, the *design* of this infrastructure needs attention *immediately*.

Action Items:

A. Mobilize the professional community, reaching out to all stakeholders, and create a board to respond to queries in an authoritative and informed manner.

B. Create tools and resources such as websites, blogs, PowerPoints, and other materials to introduce the Standards.

Recommendation 6: Focus attention on implementation at the middle grades

Discussion: Participants expressed particular concern about the implementation of the CCSS at the middle grades, where the bulk of the changes are located. These changes, coupled with the 2009 NAEP results indicating a drop in mathematics performance between fourth and eighth grade (National Center for Education Statistics, 2009), underscore the need for special considerations and attention to this level of schooling.

Action Items:

A. Design implementation systems that include strategic plans to transition to the CCSS in the middle grades, carefully monitoring the impact on learners at all levels of performance.

B. Study how students leaving elementary grades with varied levels of performance are served at middle grades, and develop clear paths for accelerated recovery for students at risk.

Recommendation 7: Develop explicit descriptions, artifacts, and tools (written, video, etc.) consistent with the CCSS content and mathematical practices to support widespread and collaborative implementation efforts.

Discussion: For teachers to successfully enact curricula consistent with the CCSS, they need exemplars of successful mathematical practices. Further, as states implement Race to the Top (RTTT), much can be learned about how to implement the CCSS in relation to the four assurances in RTTT (standards and assessments, quality instruction, longitudinal data use, and turn-around schools). It would be wise to document and share the lessons learned in the process among the implementers; these lessons should then be made available to others as they embark on implementation.

Action Items:

A. *Form coalitions among RTTT-funded states to implement the CCSS. Study that process in a few key states and use it to inform implementation in other states.*

B. *Create tools and resource materials customized in relation to each group of stakeholders to help them envision the Standards in practice.*

C. *Organize a group to review the state applications for RTTT to identify tools needed to support implementation of CCSS.*

SECTION FOUR. NEXT STEPS IN CURRICULUM DEVELOPMENT AND TECHNOLOGY

Recommendation 8: Recognize that change at scale requires designated curricular materials that align with the CCSS in content and practices.

Discussion: High-quality mathematics curriculum materials are essential to achieving the goals described in the CCSS. It is imperative to distinguish materials that genuinely align with the CCSS from those that claim alignment solely as a marketing strategy. It is also important to note that instructional materials may differ yet still be aligned to the CCSS, as the Standards do not specify curricular sequence or pedagogy. Further, it is important to recognize that *high-quality* mathematics curricula will not only align with the Standards but can offer teachers and students instructional guidance to support the creation of high-quality teaching and learning experiences.

Action Items:

A. *Organize a curriculum community to define "alignment to the CCSS" and develop a system for evaluating alignment of curriculum materials to the CCSS, including both mathematical practices and content at a deep level.*

B. *Encourage districts to continue to improve their capacity to review and select high-quality curricular materials.*

Recommendation 9: Revise existing curriculum materials/resources to reflect the changes specified in the CCSS.

Discussion: Curriculum materials and resources need to be coherent and focused, and it is not wise to add to teachers' responsibilities the need to write or assemble curriculum from a module-like database (Banilower, Boyd, Pasley, & Weiss, 2006).

Action Items:

A. *Perform a content analysis of existing curricula, identifying areas in need of additional development and/or modification to strengthen alignment and coherence.*

B. *Perform an analysis of existing curricula in terms of the development and use of mathematical practices as they relate to the content standards.*

Recommendation 10: Support and build new models and exemplars of CCSS-compatible curriculum materials/resources using meaningful organizations that are problem-based, informed by international models, connected, consistent, coherent, and focused on both content and mathematical practices. These new models should exploit the capabilities of emerging digital technologies, including model- and simulation-based, with due attention to equity.

Discussion: New comprehensive and coherent curriculum materials need to be developed that can better reflect the knowledge gained from the last 10 to 20 years of mathematics curriculum design and development. These materials also need to reflect the fact that we are living in a technology age and that the needs of the world's workforce continue to change. Careful attention should be given to materials that engage students, providing opportunities to address complex problems and applications. Additional research on learning trajectories is needed to inform this work. There is also a need to promote and implement pedagogical strategies that keep pace with technological advancements and to incorporate this knowledge in new curricula.

Any effort to develop or adapt curricula that are successful in achieving the goal of the CCSS will require a close collaboration of researchers, curriculum developers, CCSS writers, and developers of CCSS-aligned assessments. In particular, curriculum developers need room to be creative and to flourish. The knowledge that curriculum developers draw upon is only partially reflected in existing literature on student learning. For example, some knowledge about trajectories of student learning is not part of that literature, but resides only in the "craft knowledge" that comes from years of experience developing materials. Some resides in researchers' unfinished work that does not yet meet the rigorous standards that are required for publication but still represents the best and most up-to-date knowledge we have. For this reason, while the work of curriculum developers must certainly reflect existing literature, developers must also have the freedom to go beyond what is known from the research literature. The CCSS developers must be available to help clarify the intent of the Standards as new questions inevitably arise during development. Some specific curriculum development issues discussed include:

- In order to prepare for meeting a standard at its specified grade level, part of that content may need to be introduced at an earlier grade. Recommendations must address the flexibility with which the CCSS can be interpreted to prepare students for a standard that appears at a later grade.
- Since the standards vary in grain size, how much time is required for each one? How might the standards be sequenced and paced over a school year?

Curriculum developers will need to have discretion, supported by the research literature and their own professional knowledge, about when particular standards need to be learned in a focused way, when they may be best learned in a more integrated way, and how the domains should be interwoven.

A further consideration is based upon the prediction that the next generation of curricular materials will be designed based on new approaches to publishing, updating, disseminating, and adopting materials. These new models may concentrate more on how to provide services to districts in support of the use and deployment of curricular materials and the documentation and evaluation of their effects, rather than on the sale of the individual textbook.

Action Items:

A. *Make room for creativity and experimentation by providing adequate funding for new curricular design, development, field-testing, and evaluation.*

B. *Consider and investigate the use of technologies (computers, tablets, wireless devices, smartphones, calculators as learning tools) as core curriculum delivery tools.*

C. *Partner to support the development of new business models, which combine open source curricula materials and technological tools and a transition to a services model.*

D. *Capitalize on the English Language Arts (ELA) standards on "Reading and Writing in Science and Technical Subjects" by developing interdisciplinary materials linking mathematics and literacy.*

Recommendation 11: Target particular attention to course pathways at high school and strengthen the meaning of "career-ready."

Discussion: The standards at the middle grades include significant amounts of statistics and early algebra that will change both what is expected in high school and how much can be learned. The standards provide a more restricted treatment of Euclidean geometry with more emphasis on visualization and transformations. They require more statistics.

The CCSS document does not recommend or privilege a particular course pathway (algebra 1, geometry, algebra 2, or an integrated approach similar to that used through the eighth grade). *This fact must be clearly communicated to districts.* In addition, state course guidelines and textbooks for courses such as Algebra 1 and Algebra 2 have increasingly included links to statistics and, to a lesser extent, geometry topics. This suggests that the distinction between traditional and integrated curricular pathways could become blurred and that new models to combine elements of the conceptual categories in order to promote coherence and engagement might be possible.

Decisions on high school pathways should not be made on the basis of default decisions at the middle grades. That is, the commonly held perception that early acceleration means enrollment of selected middle school students in a course called "Algebra 1" should be challenged. Rather, coalitions of middle grades and high school teachers should be planning for the transition to high school and for pathways to college and careers.

In addition, the CCSS makes a distinction between STEM and non-STEM topics, which is likely to affect curricula in the third or fourth course in high school. Little advice is offered to teachers or schools about how to organize and structure classes in order to respond to these distinct expectations.

Action Item:

A. *Form a new committee from the CCSS primary writers and the school mathematics curriculum design/development community to continue to study and make recommendations regarding the organization, content, and potential audiences for high school mathematics courses.*

SECTION V. IMPLICATIONS OF THE CCSS FOR ASSESSMENT PRACTICES

Recommendation 12: Influence the quality and range of the mathematics assessed among multi-state consortia.

Discussion: There is widespread acknowledgment that what is tested and how it is evaluated and communicated to students, parents, and teachers has a profound influence on what is taught by teachers and learned by students. At this time, three consortia, *Smarter Balanced Assessment Consortium* (SBAC), *Partnership for the Assessment of Readiness for College and Careers* (PARCC), and *State Consortium on Board Examinations Systems* are competing for federal funds to development large-scale assessments aligned with the CCSS. It is imperative that the writers, designers, and implementers of mathematics curricula be involved in that development process. Curriculum designers have extensive experience in task development, know common student responses, and are sensitive to the nuances involved in the design of rubrics for scoring.

Action Items:

A. *Form partnerships among the curriculum design community and the assessment consortia in order to ensure curriculum expertise informs the assessment design process. (This includes input on writing Requests for Proposals and reviewing proposals for assessment efforts.)*

B. *Conduct an "assessment analysis" of existing curricula for assessment items aligned with the mathematical practices to share with the consortia.*

C. *Ensure that the assessments evaluate student proficiency in the eight mathematical practices as well as on the content in the CCSS.*

Recommendation 13: Use an engineering/design focus to build robust sets of assessments for learning that can influence the conduct of classroom practices.

Discussion: One of the most effective and consistent influences on improving student learning is the use of formative assessment practices in the classroom (Black & Wiliam, 1998; Wiliam, Lee, Harrison, & Black, 2004). Described also as the use of "assessment for learning," tasks are used to stimulate classroom interactions and discourse, to provide ongoing feedback to teachers to guide their instructional decisions, and to increase students' awareness of their own learning. New networked and wireless technologies have provided opportunities to make efficient and effective uses of samples of student work in this process. It is important that curriculum designers be involved in stimulating and supporting these methods of instruction and, as new digital curricular models evolve, build in such resources. Further, the development of clearer insights into the predictable sequences of learning over time provides impetus for the design of diagnostic assessments to complement other formative uses (Confrey & Maloney, in press).

Action Items:

A. *Form partnerships to develop robust exemplars of formative assessment systems.*

B. *Create exemplars of diagnostic classroom assessments and link them to proposed interventions while studying the impact on student learning.*

SECTION VI. PROFESSIONAL DEVELOPMENT

Recommendation 14: Develop curriculum-connected, concept-focused professional development in support of the CCSS across the professional continuum.

Discussion: Well-designed curricula should be resources for effective professional development, although this is only one ingredient toward large-scale professional development of teachers. Because the research shows that curriculum-connected professional development can be more effective than generic professional development, it is essential that the curriculum community combine with others to call for the establishment of a stronger statewide professional development infrastructure that combines the use of face-to-face and technology-delivered professional development across the continuum (e.g., teachers with varying levels of experience; in-service, preservice, alternative certification, etc.).

The central role that quality professional development will play in the implementation of the CCSS cannot be overstated. Therefore, professional development demands the same careful consideration by the mathematics professional development community as led to this report from the curriculum community. A similar process is needed to bring experts together to articulate a complementary action plan related to professional development.

Action Items:

A. *Hold a similar meeting of experts to focus on actions needed with regard to professional development to support implementation of the CCSS.*

B. *Challenge higher education to develop more rigorous and appropriate mathematics courses for K–12 teachers to assist them in supporting student learning and understanding as outlined in the CCSS.*

SECTION VII. CONDUCT OF RESEARCH ON CURRICULA AND IN SUPPORT OF NEW CURRICULA

Recommendation 15: Establish three types of research agendas to study curricular use in relations to the standards: general trends, including the effects on equitable outcomes; design experiments; and effectiveness studies.

Discussion: The development and adoption of the CCSS provide many opportunities and a demand for new research. Needed studies can be categorized into the three general areas outlined in *Scientific Research in Education* (National Research Council, 2002b), which respond to the question, "What is happening?" (trends), "Why is it happening?" (statistical investigations of relationships), and "By what mechanisms is it happening?" (design experiments, case studies, ethnographies). All three of these types of studies should be conducted with special attention to the impact of the changes on issues of equity, access, and pathways. Furthermore, the study of curricular effectiveness (National Research Council, 2004) outlined three types of studies—content analyses, comparative experiments, and case studies—necessary to determine the scientific effectiveness of curricular programs.

The curriculum development community is particularly concerned about learning trajectories reflected in the CCSS. Although the Standards writers based their work on some trajectories documented in the research literature, the curriculum research and development community has a great deal of knowledge beyond what is reflected in the literature. This knowledge comes from empirical evidence: working with students, observing classrooms, analyzing student work, and studying reports from teachers. If students are responsible for meeting a standard at a particular grade, the content frequently needs to be introduced at an earlier grade. In order to *achieve* the goals of the CCSS, curriculum developers need to have the flexibility to create quality materials that reflect what they know about student learning.

There is also a need to reflect the fact that we are living in an electronic age, which can profoundly affect the next generation of curriculum materials and related tools. These changes will be reflected in the delivery of curriculum, its relationship with assessment and data collection, and the use of technologically rich tools for learning and doing mathematics. Moreover, since the needs of the world's workforce continue to change, new initiatives should draw on opportunities in emerging areas of engineering, career, and technical education. There is much interest in having an open source set of curricular materials founded on knowledge gained from recent efforts. All of these innovations merit support for design and development and for the study of their effects on teaching and learning.

Finally, there are clear indications of a need for new business models of curriculum design and delivery and support services connected with curriculum use and results. Research should be supported to investigate these new models.

Action Items:

A. *Provide funding and support for the development and related study of new mathematics curricula materials and tools.*

B. *Conduct design experiments to create new models for mathematics curricula and to develop a stronger empirical base in learning trajectories.*

C. *Conduct studies of curricular effectiveness.*

D. *Examine and monitor the impact of the CCSS on equity in course selection, in levels of performance, and in access to college and career opportunities.*

SECTION VIII. POLICY AND ORGANIZATION

Recommendation 16: Organize a curriculum design and implementation community with expertise in curriculum-related implications of the CCSS and seek support for continuing interactions and contact from outside parties.

Discussion: The curriculum developers and implementers in this community know that change of the magnitude of the CCSS is an educational issue, a political issue, and a cultural issue. It is a systemic issue within each of these realms. Successful implementation requires attention to each of these areas. The participants at this conference have had significant experience with systemic change of this type. Therefore, a process is needed for this group to interact with Achieve, NGA, CCSSO, and the NCTM-NCSM-AMTE-ASSM "CCSS Implementation" Committee on issues related to the CCSS.

Action Item:

A. *Establish a community of mathematics curriculum developers/designers called "Design and Implementation in Mathematics Education (DIME)." As a first task, DIME should prepare an Executive Summary of this report and communicate it to the groups identified above.*

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