Standards-Based Math Education by Design

Needed, a Phase II of College and Career Readiness Standards

A WHITE PAPER BY GORDON FREEDMAN

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The math education equity problem can only be addressed with full transparency on what math is actually being taught and learned daily.

Although the Common Core State Standards for Mathematics (CCSSM) and similar state-specific math standards were adopted beginning in 2010, the United States has shown little improvement in students' math achievement. In fact, achievement continues to fall short of other high-performing countries and shows stark disparities among states when compared to the highest performing states in the country.

This paper provides the framework for a Phase II of the mathematics standards, which is needed to accelerate improvements in students' learning and understanding in math by concentrating on clearer implementation frameworks. To do so, the paper advocates for the development of a system that catalogues, at the level of each math standard, all students' learning activities and performance on math assignments, problem sets, projects, and formative assessments across grades vertically and linked to the appropriate state standards. By enabling multiple grade data analytics that can inform instruction, clear patterns will emerge, showing where attention is required.

At present, no such system exists. Teachers and school leaders are unable to identify the strengths and weaknesses of each student in relation to the math standards. Without such a system, it is not possible to develop an accurate picture of all student trajectories in a progression-based model of math proficiency.

The creation, implementation, and wide adoption of a detailed inventory of standards achievement by schools and districts would enable teachers to refine their instructional strategy for each student and increase the likelihood that all students will achieve grade-level proficiency in math. Additionally, such a standards accounting system could provide feedback to teacher education programs and to student teachers as they prepare to teach math effectively. A Phase II of the math standards, as described in this paper, would ensure the success of students and provide an equity monitoring framework for teachers and districts as envisioned in college and career readiness standards.

Introduction: America's Math Problem

The decline in mathematics proficiency in the U.S. has been recently confirmed by state, national and international summative testing.[1, 2, 3]

At the same time, many states will soon see their first students complete the full Common Core State Standards in Math (CCSSM) since the standards were introduced in 2010.

Undoubtedly, judgements will be made on whether the math portion of the Common Core is working. The question raised in this white paper, "Standards-Based Math Education by Design," is whether there is sufficient knowledge about CCSSM implementations to provide answers about the:

- Fidelity of CCSSM implementations (reporting, data structures, common assessments)
- Nature of the professional development of teachers in the CCSSM (is it uniform?)
- District commitment and management to monitor the integrity of implementations
- Ability to uniformly serve students who struggle, have equity and language challenges

The conclusion drawn herein is that the adoption of the CCSSM, and similar state mathematics standards, in principle was a large national undertaking that has concluded its first phase, official state adoptions. However, such adoption does not speak to whether it is working well or better because outside of annual testing, there is no uniform data at the standards level to make such judgment.

While preparing lessons or learning math, how many of us think about the fact that math is driving the information age, that algorithms define our era, that behind every digital game, email, text, social media, website, stock market trade, or consumer purchase, math is busily working in the background? All of us are surrounded by and defined by numbers – calculations, predictions, data analysis, net worth, even taxes. Yet math remains a national Achilles heel. Why? Are our efforts too narrow and our imaginations too dim to solve this problem?

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[1] https://www.act.org/content/dam/act/unsecured/documents/National-CCCR-2019.pdf
[2] "The 2018 Brown Center Report on American Education"
[3] https://www.oecd.org/pisa/PISA%202018%20Insights%20and%20Interpretations%20FINAL%20PDF.pdf

Despite the implementation of the Common Core State Standards for Mathematics (CCSSM), developed with the goal of raising math achievement for our students, the U.S.'s poor showing in math achievement, both across the country,[4] and compared to our global peers, continues. Is this due to the standards themselves, an unmonitored and possibly uneven implementation, or other social and cultural factors?

These are important questions as math itself is an essential ingredient in student success, work and life options, and the vibrancy of the U.S. economy. It is a necessary component of U.S. defenses and world economic standing. Those who are most successful with math view it as something to understand, think about, and use, even as an art form. Yet, in our recent past, math has been taught as a series of things to remember and do. Is our country's focus still too much on rote procedures and not enough about math in the real world and the concepts behind it?

I. The Surprising Acceptance of the Common Core Math Standards

The developers of the CCSSM spent considerable time with higher education, businesses, governments, and employers determining the math foundations that are needed to produce successes for individuals,[5] fields of study, and economic contributions beyond school. They studied effective math teaching and learning around the world. They then enlisted governors and others to make the case for the Common Core to the country.

Despite the grumblings about the Common Core State Standards in Math (CCSSM), such as parent protests, conspiracy theories, states renaming the Common Core and replacing its primary tests, the CCSSM has become the predominant organizing principle, or curricular architecture, for teaching math in the United States.[6]

All fifty states and the U.S. territories have adopted rigorous state mathematic progression content standards and they all measure summative math progress annually. Thus, the Common Core State Standards in Math (CCSSM) are now the foundation of almost every state's K-12 math teaching and measurement of progress. Even those states not utilizing the CCSSM have very similar, if not nearly identical, math standards and annual summative exams.[7]

By now, there is general agreement on what classroom math instruction is and how it should progress within each grade and across the grades in the U.S. and its territories. The standards were explicitly designed and developed to be a progression of math competencies, specifically building upon each other, until mastery is possible in Algebra and beyond.

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[4] https://nces.ed.gov/nationsreportcard/mathematics
[5] http://www.corestandards.org/about-the-standards/development-process
[6] https://www.prnewswire.com/news-releases/eureka-math-the-top-pick-of-teachers-nationwide-300253253.html
[7] https://www.edweek.org/ew/section/multimedia/map-states-academic-standards-common-core-or.html

The progression in K-8 is divided between K-2, which concentrates on arithmetic understanding, relying heavily on the visualization and analysis of whole numbers and number line operations, whereas grades 3 to 8 concentrate on the introduction of fractions, fraction operations, decimals, long division, proportionality, and more complex operations with integers leading up to Algebra.[8]

These progressions introduce new learning at three main time points: whole number understanding at Kindergarten, fraction and decimal work in grade 3 and proportionality beginning in grade 6. Additionally, measurement and data is a significant area of focus for Kindergarten through grade 5, as is statistics and probability for grades 6 to 8 and geometry from Kindergarten through grade 8. Everything in between is a careful building standard-by-standard of understanding.

In addition to the implementation of new math learning standards, there is a voluminous amount of activity on the periphery of K12 math: K12 math education literature, meta-analyses of K12 math performance, cognitive investigations of math learning, state and national math performance data, math improvement programs and tool development, teacher development programs and literature, to name a few.

There is no shortage of research, interventions, comparative analyses, or products. Whole industries, parts of government agencies, wealthy philanthropies, policy organizations, teacher associations and educational publishing companies now exist or subsist with the specific purpose of improving the teaching and learning of math.

Notwithstanding these enormous efforts over many years as well as extraordinary expenditures, performance gains in math are minimal to negative, especially in lower socio-economic and some racial/ethnic subgroups. The latest report, the Nation's Report Card (the National Assessment of Educational Progress), reports scant encouraging results in 4th grade and disappointing 8th grade math performance nationally.[9] This is not to say there are not gains in some economically-challenged schools, but the national norm reflects a drop in middle school performance despite gains in early elementary school. Research supports the idea that the drop in 8th grade math performance will translate directly into a decline in high school math success, college attendance and completion, and STEM, financial, medical and engineering career production.[10, 11]

The success in installing the CCSSM or its equivalents nationally, while a giant step in the right direction, doesn't seem to have been enough. The daily focus in classrooms seems to have been drained of the larger purposes and promise of the standards and is essentially a numbers game of curriculum and instruction, testing and reporting. It's simply schooling all over again, as textbooks still look and feel like textbooks, and the new standards are still viewed as "laundry lists" of topics to cover at each grade, not progressive steps in overall math comprehension and capability that will arm students for life and work and, possibly, enjoyment.

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[8] https://achievethecore.org/category/774/mathematics-focus-by-grade-level
[9] https://nces.ed.gov/nationsreportcard/mathematics
[10] https://www.act.org/content/dam/act/unsecured/documents/ForgottenMiddleSummary.pdf
[11] https://www.niu.edu/mathmatters/careers-jobs/index.shtml

It is likely that the CCSSM have through practice been molded to fit into the comfort zones of both teachers and school districts. Instruction is often largely devoid of imagination in structuring, encouraging and tracking math teaching, and learning. Many times, it fails to define math in such a way that it can find its place in today's vibrancy of the information age.

II. No Surprise Here, Schooling is Cemented into Grade Level Practice

Having math progression standards, and the state and territorial commitment to them, is only the beginning. Adherence to the CCSSM, and the ability to adequately track each student's mastery over time is badly needed and the inability to do so is one of the factors leading to math failure in general. Math learning is intensely personal and often cannot be accomplished solely through the classroom structure.

- Currently, the teaching and learning of math standards, on a daily and/or weekly basis is largely "untracked" standard-by-standard, student-by-student, within any single grade or between multiple grades.
- Standard-by-standard, student-by-student data over time would service the intention and investment of the progression-based standards and the states' commitments to a progression-based model.

Without such management and recording of learning within the standards there is no body of evidence to show how student mastery of the standards actually progresses over time. Nor is there a way to see trends in performance across standards for individual students or classrooms of students to identify consistent trouble spots or areas of understanding. Quarterly student report cards, for example, only report individual student progress with respect to on-grade-level work. Students who begin the school year behind grade level may in fact demonstrate substantial growth in achievement, but there is no way for this growth to be measured or reported.

- Outside of a few proprietary math learning technologies, the micro-data associated with standard-by-standard accounting for each student across time, with the potential to truly inform instruction, does not exist.
- There are few school math departments, curriculum heads, or principals in school districts who "own" and manage math progression data longitudinally, especially across the K-12 segment boundaries of elementary, middle and high school.

- The data that do exist are largely annually reported from summative state assessments and mostly used for accountability purposes and not for systematic analysis to increase standards progression acquisition over time.

Where formative-style assessment (quizzing and interim testing) is systematically conducted, it generally occurs in wealthier or well-funded low socio-economic schools: schools and districts that can afford proprietary assessment systems.[12] However, in these cases, the data are generally used for monitoring current student performance, not for deeper analyses to improve math progressions within grades and across grades by individual students.

- If such standards-based formative assessments, and the ability to track the data from them, were freely and universally available, intervention patterns could be detected and acted upon allowing schools and districts to report progress in the math progression across grades more precisely.
- This would lead to an on-going data analysis to communicate to next grades, the strength and weaknesses of incoming students.
- It would allow districts to plan resource allocations for math better, and it would enable them to examine their ability to prepare college and work ready students.

Thus, while the standards are considered to be reasonable and of high quality, and are largely uncontested,[13] the practice and measurement of their use is not a programmatic goal. This is somewhat akin to agreeing with having rules of the road for driving, but not requiring testing or the enforcement of their use.

III. Can We Have a Common Core Math, Phase II?

How is it that reasonably strong math standards exist, yet standards-based, recorded, systematic and universal formative testing of achievement in those standards is not part of the standards movement?

[12] https://edpolicy.stanford.edu/sites/default/files/publications/creating-systems-assessment-deeper-learning_0.pdf
[13] https://fordhaminstitute.org/national/research/state-state-standards-post-common-core

It could be viewed, that the adoption and acceptance of the standards is a large national success story that can be considered the "first stage" in a longer effort to measure, manage and support math learning progressions longitudinally.

- CCSSM Phase I could be considered "adoption" and "acceptance."
- CCSSM Phase II could be considered "implementation" and "measurement."

While the logic of a two-phase implementation process appears sensible, it is an unusual suggestion to go beyond standards acceptance to standards assessment, measurement and tracking by standard and by students, *given that schools and districts generally manage "horizontally" grade-by-grade and not "personally" and "vertically" student-by-student over time.*

Thus, we are left with half of a solution. The standards are in place and they are largely utilized as part of, or *informing,* the teaching and learning culture. That is the first half.

The second half would be managing and measuring by every standard, every student, across all grades with the explicit understanding that the standards exist as progressions, learning standard by standard in a scaffold.

The CCSSM are not "one-offs" to be memorized standard-by-standard, but understanding to be internalized in each student as an academic, life and work foundation. Perhaps the pushback to such a second stage would be an inherent framing of schooling which is currently dominated by day-to-day preparation, teaching, and management in each separate classroom, in each grade level. Currently, little thought is given, or planning done that goes into tracking individual students' math progression through grade levels.

Could creating a finer-grain system of data standards for tracking CCSSM assignments, problem sets, student projects and reporting formative assessment results and progression measurement be Phase II for the CCSSM, as a logical development in response to the math performance crisis in most states and districts?

- District or school math managers could own the Phase II implementations and measurement, an assigned role that would allow teachers and schools to focus on CCSSM progression success.
- Likewise, the state agencies that administer the end of year summative state tests would need to give proficiency results actual success and failure panels on the individual standards and publish longitudinal results where patterns are clear and specific.

While schools, districts, and states are well aware of the big data reporting relative to gains and failures in math, little effort, imagination or work is done to rectify or explore what else might be done in a more strategic, multiple grade, sense. Notwithstanding district strategic planning, education administration is largely day-to-day tactical, while the academic subjects, including Math, requires a vertical student strategy.

Math teaching, learning and analysis could become strategic by turning it into a cross-district role to be populated by professionals who can define assessment in multiple grade goals and strategies, manage the data analysis, and feed results back to teachers, staff, parents and students across district segments. This might be a small investment for a comparatively large return not only to education, but to the economy and the futures of the students.

IV. How to Start CCSSM Phase II

There may be multiple ways to start a CCSSM Phase II. Here are four dimensions of change that might be addressed in a Phase II of CCSSM, tuning for success in math progression learning.

1. **Implementation Success** — Is CCSSM being implemented well to begin with? Where is this happening or not happening? What could make a difference? Where the CCSSM is not being implemented well, why isn't it and what is or is not being done? Can we "instrument" the CCSSM with common data standards so that everyone is on the same standards playing field?

2. **Identifying Barriers** — What do we suspect is making math, despite the CCSSM, such an equity issue where students are stratified by performance along racial/ethnic and socioeconomic dimensions? What are problems or areas of math that create the largest barriers? Fractions is one suspect, but why? What has worked well in certain places?

3. **Data Management** — Would better performance and progression tracking by standards, by students over time, give us sufficient data to establish true CCSSM adoptions? This can help facilitate identifying patterns of failure and success and enabling differential responses to learning difficulties.

4. **Professional Standards** — Where should the effort be placed on improving teacher math understanding and diagnosing of student work? What is the role for schools of education, for district professional development or new kinds of CCSSM certifications?

V. Avoiding the Math Standards Trapdoor, "Trading Concepts for Procedures"

The largest contribution the Common Core Math Standards has provided to teachers and schools is an emphasis on conceptual understanding as opposed to procedural knowledge only, in the form of memorization and schemes for remembering. This means concentration on what the math is, how numbers work, why it is studied, and how it used in everyday life, rather than the emphasis on "drill and kill" memorization that was the norm before the Common Core.

- Despite the best efforts of the CCSSM and its variants, however, math learning in U.S. classrooms remains stubbornly locked on memorization and not the underlying dynamics of mathematics.[14]
- Teachers largely teach math as it was taught to them. This means the deeper aspects of the Common Core, or the conceptual emphasis, is not being passed on to students as intended. Can teachers rethink how they learned?[15]
- It turns out, not surprisingly, that stories, narratives and real-world examples can contextualize math operations in ways that make them relatable. Compared to teachers in Japan and Hong Kong, U.S. teachers use analogies just as frequently but are less likely than their Asian counterparts to use analogy-based instruction in a manner that encourages active reasoning by students.[16, 17]

And, even when the concentration is on conceptual understanding, through problem solving or students writing about their math and their creation of real-world projects, what is still lagging is building standard-upon-standard and recording this progression by student no matter the math concept being studied. The conceptual and practical needs to be tied to a data framework.

But what about skills and calculations?

There is no question that understanding concepts is critical, but not at the expense of procedural learning, such as, "I understand something conceptually but am unable to do it practically." What is needed is a balance between mathematical understanding and mathematical procedures.

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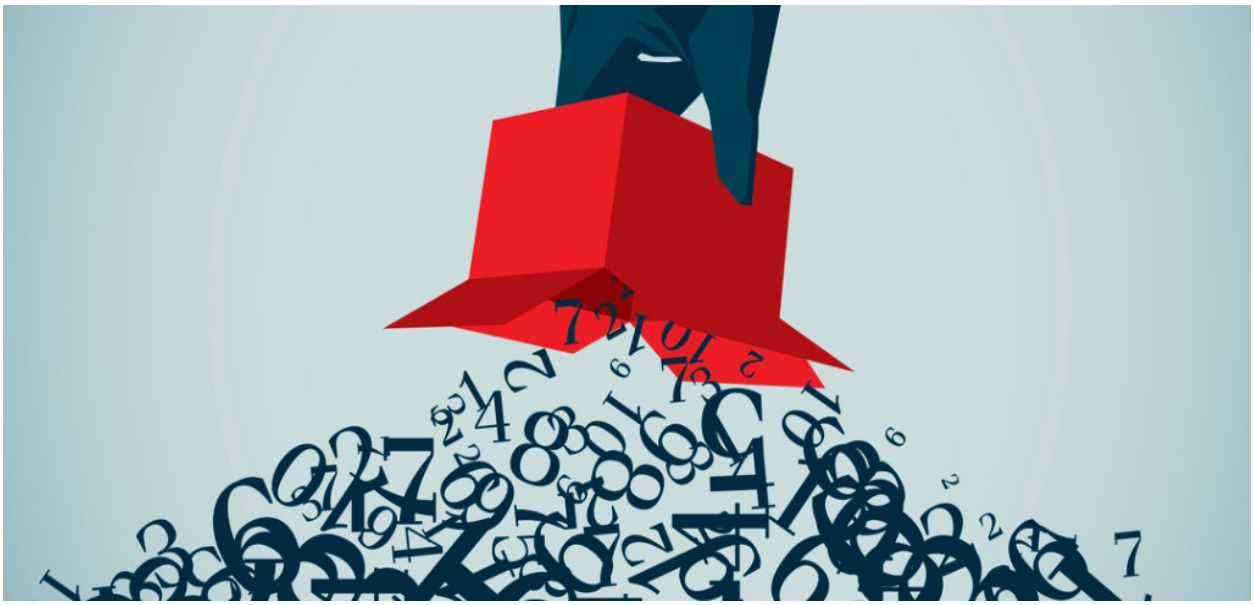
[14] https://www.youcubed.org/evidence/fluency-without-fear
[15] https://www.wired.com/2016/10/meet-new-math-unlike-old-math
[16] "MATHEMATICS: Cognitive Supports for Analogies in the Mathematics Classroom"
[17] Analogy and Higher Order Thinking: Learning Mathematics as an Example"



The objective of the Common Core, summing up years of research funded by the National Science Foundation and the Department of Education[18] is on *quantitative reasoning* and *mathematical practices;*[19] being able to apply what is learned broadly, not just in problem sets, as well as understanding its significance in the world. This two-fold intent of the standards may provide a confusing message for some teachers who end up emphasizing understanding at the conceptual level over adequate activity at the procedural level. Again, balance is the goal.

While there are assessment systems available commercially which can be used to track the standards learning at a "micro" or competency level, few are designed for purposes other than general testing of students and managing teacher procedural "workflow." Writing about math and reflecting on it in real and abstract forms would allow math learning to move toward *numeracy,* not mimicry.

There is little way to tease apart whether conceptual learning and operations are tied together effectively in the teaching or the learning without a way to record teaching, learning and assessment activity related to each standard.

Many skilled teachers are able to balance standards teaching and learning by concepts, procedures and projects and know who needs what kind of help. But these teachers are talented practitioners of which there are far too few to provide adequate coverage for the math need in any given school and district, especially in impacted schools and those with high concentrations of low-income and minority populations.

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[18] https://www2.ed.gov/programs/racetothetop/index.html

[19] http://www.corestandards.org/Math/Practice

VI. Moving from Within-Grade Tactics to Multiple-Grade Strategies

There is a difference between tactics, or day-to-day math teaching and learning, and a math teaching, learning, and analysis strategy. The methods to ensure that math teaching and learning is accomplished at the highest rates possible *over time* require new structures to carry the intent of the Common Core math progressions into a second stage reality, or CCSSM Phase II.

The leap between tactics and strategy is not insurmountable.

- What is missing is the publicly-available software that allows longitudinal tracking, by standard and by student, and analysis of math standards performance over time within the CCSSM progression.
- The other missing component is the need to include teachers and aides in the same system, giving them the opportunity to learn and/or sharpen that which they are providing to their classes standard-by-standard, student-by-student, as well as routine access to the data they need to react more precisely to clearly visible unmet needs or, equally, to demonstrate clear and repeatable patterns of success.

There is an understanding in literacy development that students must progress through successive reading levels, rather than jump from where they are to a much higher one. Inherent in the leveled literacy movement is the ability to offer targeted instruction and both measure and report student growth. By design, today's math content standards reflect a progression of understanding that requires this same successive movement.[20]

The architecture for CCSSM, or its counterparts, in Phase II would include using new methods and management technologies that rely on a detailed inventory of standards achievement, by standard and by student, across grades. Such an inventory, whether on paper, in software, or in assessment and data reporting systems would stitch together the intent of the CCSSM as a) math learning as a progression, b) managing learning concepts, procedures and real-world examples, and c) doing so by student, by standards, across grades.

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[20] https://www.nctm.org/Standards-and-Positions/Position-Statements/The-Role-of-Elementary-Mathematics-Specialists-in-the-Teaching-and-Learning-of-Mathematics

VII. Attacking the Weak Points in the Value Chain

The mathematics education value chain is far more than carefully managing students in-grade, between grades, across school segments and into higher education and the workplace.

Math sets itself apart from the other subjects by the fact that it is not viewed positively for the most part, and to succeed in having math understanding is an intricate lattice of learning that stretches across years, progressing in baby steps. It requires grit and persistence by students and support from teachers, staff, administrators and parents.

To gain mathematical understanding and fluency, these baby steps have to be taken in sequence. Some of the steps are more important, or more critical, than others for later learning, but the order of the steps is critical. Skipping over any of them, or allowing any of them to remain insufficiently understood, leads to gaps in learning that compound over time. When any part of the math foundation is weak or inadequate, the deficiencies will impair if not cripple later math learning.

The developers of the CCSSM, in laying out a progression of math learning over time, underscored that certain standards were "core" to "the Core," meaning that some standards are more heavily weighted, in that they are important, *instrumental,* to later math learning.

- If teachers did little more than ensure that the "weighted" standards were learned without fail, significant gains could be secured, and remediation pathways built, for strong progressions in math learning.
- If teachers were provided resources that not only pointed out "weighted" standards but also provided the means to make use of this information (such as linking them to related standards at earlier grade levels), differential instruction could lead to the mastery of these standards, and missing components necessary for that mastery could be identified.

In this kind of framework or architecture, a Phase II architecture, teachers would not necessarily need to "know the math," but they would need to know how to diagnose what is missing in every student or in groups of students and how to remediate for the deficiencies.

If an architecture or detailed inventory of standards achievement existed, teachers would know where the potential trouble spots were, even if they themselves were not yet completely steeped in the math progression of a particular concept. They could work their students through the difficult bits and celebrate those that are easier to accomplish. Targeted gap analysis would allow for targeted pre-teaching on an individual or small group basis. This would facilitate growth for all students, as well as allow for the reporting of this growth.

For teachers, who are challenged by both the math itself and the diagnostics process, easy-to-understand procedures and public, open, technology could support, not replace, lesson preparation and classroom instruction and textbooks. Hopefully for those teachers, a prescription to move beyond implicit student typecasting in math or implicit racial, cultural, and gender math bias could go a long way toward a wholistic approach to math teaching and learning improvement.

Conclusion: Build the Future, Stop Reiterating the Obvious

Math is unlike any other curriculum or field of study in that it builds upon itself in successive stages, precisely.

A lack of math learning doesn't on its surface seem to inhibit the ability of students to move forward with other learning, though successful math learning will lead to higher rates of success across the curriculum.[21, 22,23] The fact that math is not seen as needed to succeed in general, causes math to be seen as its own unrelated entity.

Math is sequestered mostly as a school-only activity unless parents and siblings actively work with their learners. While there are math "academies" and summer programs for students to gain extra math experience or exposure, these are largely standing in for what could have, or should have, occurred in school.

Unlike language, writing or English, math is not used consistently throughout the day. It is not reinforced in speaking, texting, computer use, or in daily calculations.

We know that many of the young people who desire to be elementary school teachers have great compassion and interest in helping early learners, but little core math knowledge.

The compassion and passion to teach elementary school is a strong impulse. To pursue that impulse without the requisite math knowledge is the first weak link in the math education value chain.

The responsibility for math deficiency in teachers and/or the choices college students make by choosing an elementary education career does not entirely belong to those prospective teachers, but rather to the higher education programs that advise those students and then certify them as elementary school educators.

- A Phase II system, accessible by colleges and universities who prepare, certify and provide professional development, would enable higher educators to re-configure their teacher preparation programs and graduate teacher candidates who are truly ready for teaching math today. Or, at least offer the option of math certification which would be highly desired by schools.
- Rather than graduate elementary and middle schools teachers without math certification, there could be certifications that can be earned to be able to differentiate and to incentivize teachers to acquire that knowledge, or for math-capable students to be encouraged, or incentivized, to teach in the earlier grades.

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[21] "College for all: Gaps between desirable and actual P–12 math achievement trajectories for college readiness."
[22] "Early predictors of high school mathematics achievement"
[23] "Preventing student disengagement and keeping students on the graduation path in urban middle-grades schools: Early identification and effective interventions"

The math deficiencies in students begin in K-5 directly as a result of their teachers, lessons and materials. Misconceptions carried forward are part of the measured decline in math proficiency starting in 4th grade.

Many skilled teachers are able to balance standards teaching and learning by concepts, procedures and projects and know who needs what kind of help. But these teachers are talented practitioners of which there are far too few to provide adequate coverage for the math need in any given school and district, especially in impacted schools and those with high concentrations of low-income and minority populations.

Finally, the public will to improve math education as an equity, economic and community good, and the public discourse leading to standards tracking over time, is necessary. What is not missing are voluminous reports, state data reporting, and researchers lamenting and documenting poor math performance. The effort and analysis of the math measurement community and policy critiques should be turned into demonstrable efforts to build the machinery and practice to measure, remediate, track and analyze in grade and across grades by student.

This should be accompanied by public campaigns to put math success squarely in the agenda of all schools, districts and states.

Please Join the "Why Math Matters" Conversation

Help us take state math standards to the next level of implementation, fidelity, and relevance. This is an important topic that deserves much greater scrutiny and collective action. NLET will be exploring the economic and social consequences of math learning and opening dialogues through the Why Math Matters program to counteract prevailing sentiments about math difficulty and relevance. Public dialogue across sectors is the only way to address the equity issues produced by current math education.

Comments and connections are welcome. Contact us at info@NLET.org.

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