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Changes in Math Instruction and Student Outcomes since the Implementation of Common Core State Standards in Chicago

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Julia A. Gwynne and Sarah Cashdollar

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Introduction

Policymakers have grappled for decades with how to promote higher levels of student achievement among students in the K-12 system. Concerns over years of mediocre performance on international assessments, as well as persistent achievement gaps among students from different racial, ethnic, and socioeconomic backgrounds, have led to waves of reform targeting what students should learn and be able to demonstrate in school.[1] The most recent, and perhaps most ambitious, example of these standards-based reforms is the Common Core State Standards (CCSS). These standards identify a set of skills and knowledge that students should master at each grade level in order to be ready for college and careers. They prioritize higher-order thinking skills and in-depth content coverage, and both the math (CCSS-M) and English/language arts (ELA) standards (CCSS-ELA) are considered to be more challenging than previous standards in most states around the country.[2]

The shift toward more challenging skills and content is what policymakers hope will lead to improvements in student learning outcomes (see the inset box entitled **Elements of Effective Classroom Instruction: Academic Demand and Teacher Support**). But new standards by themselves are unlikely to raise achievement without shifts in instructional practice. Changes in professional development may be needed so that teachers understand the new standards and have effective strategies to teach to them. Additionally, students may need more support from their teachers to prevent academic struggles as they experience new, more challenging standards.

This brief examines how math instruction and student outcomes have changed since the implementation of the new mathematics standards in Chicago Public Schools (CPS) in 2014-15. This study builds on an earlier report by the University of Chicago Consortium on School Research (UChicago Consortium) that documented the district's efforts to support school staff's transition to the new standards through administrator and teacher professional development. The report showed considerable variation across schools in the amount of standards-related professional development teachers participated in.[3] It also noted that at the same time the district first began providing professional development related to the new standards, it was in the process of launching a new teacher evaluation system, a policy that was also aimed at improving teachers' instructional practices. Given the near simultaneous launch of these two policies, disentangling the effect of each policy on any subsequent changes in instruction or student outcomes is challenging. However, we leverage the fact that schools differed considerably in the amount of standards-related professional development their teachers participated in to assess whether there were larger changes in students'

[1] National Academy of Education (2009).
[2] Common Core State Standards Initiative (2018a); Carmichael, Martino, Porter-Magee, & Wilson (2010).
[3] Gwynne & Cowhy (2017).

instructional experiences and achievement in schools where teachers participated in more professional development than in schools with less participation.

Specifically, we ask the following questions in this brief:

- How has math instruction changed since the implementation of the CCSS-M in 2014-15 in schools with differing levels of standards-related professional development?
- How have students' math outcomes, including test scores and grades, changed since implementation of the CCSS-M in 2014-15 in schools with differing levels of standards-related professional development?

In the next section, we describe the Department of Mathematics' strategy for preparing CPS teachers to teach the CCSS-M. The third section examines trends in students' reports about instructional experiences in their math classrooms among schools with different levels of professional learning related to the new standards. The fourth section looks at trends in math test scores and grades, also by the level of standards related professional learning. In the final section, we highlight key findings from this study and discuss their implications for policy and practice.

Elements of Effective Classroom Instruction: Academic Demand and Teacher Support

Given the aim of the CCSS to increase academic demand and promote higher-order thinking, many educators and researchers are optimistic that the new standards will improve student academic outcomes. Research has consistently shown that students learn more in classrooms that are academically challenging. For example, students who report that their teachers expect nothing less than their full effort and require students to engage in higher-order thinking rather than rote memorization tend to score higher on standardized achievement tests and feel more academically engaged.[A] These findings are consistent with studies showing that students perform at higher levels in countries and states where curricula are more rigorous.[B]

Although classrooms with rigorous instruction have higher levels of student learning, increasing demand without attention to other relevant aspects of the instructional environment may have unintended consequences. For example, previous reforms aimed at increasing the level of instructional demand in CPS did not yield expected results. The College Preparatory Curriculum for All policy eliminated remedial courses and required all students to take college preparatory classes. But rather than increasing college-going rates or improving test scores, the policy resulted in higher numbers of course failures and lower grades.[C] Research has shown that students with a history of low achievement may become disengaged and stop trying when academic rigor increases without simultaneous efforts to help them meet the new demands.[D] They may feel their assigned work is too challenging for their ability level, leading them to become frustrated and act out in disruptive ways, thereby creating disorderly learning environments. This disengagement and decreased classroom order leads to worse academic outcomes overall.[E]

In order for efforts to increase academic challenge to result in desired student outcomes, other changes to the instructional environment in the form of increased scaffolding, assistance, encouragement, and other forms of support may also be needed. For example, socioemotional and academic support are critical, particularly when coursework is demanding. Students who experience strong, caring relationships with their teachers are more engaged and score higher on standardized achievement tests,[F] and students who report that their teachers provide monitoring, feedback, and assistance earn higher grades.[G] In academically-demanding classrooms, teacher support and a strong sense of school community creates a bridge to help students meet what might otherwise be daunting levels of challenge, and this affirmation and scaffolding may be especially important for students considered academically at risk.[H] In line with these findings, research has shown that ideal school and classroom learning environments are characterized by a combination of demand and support.[I]

[A] Gates Foundation (2010); Fischer, Bol, Pribesh, & Nunnery (2013).
[B] Lee & Ready (2009); Schmidt & Houang (2012).
[C] Allensworth et al. (2009).
[D] Bandura (1986); Bouffard-Bouchard (1990); Lent, Brown, & Larkin (1984); Shernoff, Csikszentmihalyi, Shneider, & Shernoff (2003).
[E] Allensworth, Gwynne, Pareja, Sebastian & Stevens (2014).
[F] Fischer et al. (2013); Gregory & Weinstein (2004); Pianta, Belsky, Vandergrift, Houts, & Morrison (2008); Rollan (2012); Roorda, Koomen, Spilt, & Oort (2011); Sakiz, Pape, & Hoy (2012).
[G] Allensworth et al. (2014).
[H] Allensworth et al. (2014); Gregory & Weinstein (2004); Roorda et al. (2008); Shouse (1996).
[I] Allensworth et al. (2014); Goddard, Sweetland, & Hoy (2000); Lee, Smith, & Croninger (1997); Sandilos, Rimm-Kaufman, & Cohen (2016); Lee & Smith (1999).

Preparing for the CCSS-M in CPS

Illinois adopted the CCSS in 2010, and CPS began gearing up for the transition to the new standards soon thereafter. The Department of Mathematics partnered with two local universities to develop and provide professional learning on the standards to network leaders, administrators, and teachers. Additionally, the Department also created an online repository of standards-aligned resources. Teachers were expected to have incorporated CCSS-M by 2014-15.

The professional learning program developed by the Department of Mathematics, in collaboration with its university partners, had two components, the first of which was a districtwide strategy that relied on a "train the trainer" model to provide workshops three to four times per year to all teachers who were responsible for implementing CCSS-M (see box entitled **Providing Standards-Related Professional Development to CPS Teachers: The Network Partnership**). During the first year, 2012-13, workshops were offered to teachers in sixth grade through high school; training was optional, although most schools chose to participate. In the second and third years, 2013-14 and 2014-15, participation was required and separate workshops were offered to teachers in preschool through fifth grade and to teachers in sixth grade through high school. In 2015-16, the district continued to offer standards-related professional development, but participation was once again optional. The content of professional learning was focused on the provision of high-quality math instruction, rather than a more narrow focus on merely understanding the content of the new standards, and it was coordinated across all years so that teachers were exposed to new components of CCSS-M in each year.[4] Even though teachers weren't expected to have fully incorporated all of the new standards until 2014-15, they were asked to incorporate some of the key instructional strategies presented in professional development workshops beginning in 2012-13.[5]

The second component of the professional learning program included more intensive support to a subset of schools referred to as "Deep Support" schools. This support included participation in a professional learning community, and in some cases, instructional coaching. It was offered in addition to the districtwide workshop series. The district identified four networks of schools that could receive this support, and within those networks, schools could elect to participate or not.

The 2017 Consortium report showed that, consistent with the districtwide plan, the typical CPS teacher reported participating in one or two professional development sessions per semester (or three or four sessions per year). However, a surprising number of teachers—around 15 percent of elementary teacher and one-quarter of high school teachers—reported no standards-related professional development in each year.

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[4] In the first year of mandatory participation (2013-14), professional development sessions focused on Standards for Mathematical Practice, Expressions, and Equations (sixth grade through high school) and Functions eighth grade through high school). In the second year, the focus was Standards for Mathematical Practice, Operations, and Algebraic Thinking (preschool through fifth grade), Number Operations in Base Ten (preschool through fifth grade), Expressions and Equations (sixth grade through high school), and Ratios and Proportional Relationships (sixth grade through high school; Chicago Public Schools, n.d.).

[5] For example, in 2012-13 teachers were expected to incorporate Math Talks and MARS Tasks into their instruction. They were also asked to "provide feedback and praise that promote a growth mindset" (Chicago Public Schools, n.d.).

This may have been due to the decentralized way in which professional development was provided (see box entitled **Providing Standards-Related Professional Development to CPS Teachers: The Network Partnership**). At the other end of the spectrum, some teachers—23 percent of elementary teachers and 14 percent of high school teachers—reported participating in standards-related professional development workshops at least monthly.[6]

Many of the findings about math standards implementation in CPS mirror the experiences of teachers and principals across the country. In a 2015 survey of teachers and principals across five states implementing the CCSS, Kane and colleagues[7] found that teachers received 4 and a half days of standards-related professional development on average in the 2013-14 school year, while administrators received about 5 days.

Providing Standards-Related Professional Development to CPS Teachers: The Network Partnership

In a district as large as CPS, it can be challenging to design a professional learning program that all teachers can participate in. To prepare teachers and administrators for the transition to the CCSS, the district used a "train the trainer" strategy, which capitalized on the district's organization of schools into different networks (i.e., The Network Partnership). Each network sent a group of experienced teachers to attend full-day district-sponsored professional development sessions three to four times per year. Teacher facilitators then replicated these sessions at network Teacher Leader Institutes, which were attended by teachers from each school within the network. The teacher leaders were then expected to share what they had learned with their colleagues in their schools. The district considered this three-tier distributed approach to be the best way to reach its sizeable workforce, but this model also meant that it had less control over making sure that each and every teacher received professional development on the new standards.

Studies of CCSS implementation across standards-adopting states also found that teachers have made significant changes to their instruction in response to the standards. These instructional changes include increases in standards-aligned practices such as requiring students to use multiple methods to solve problems and explain their mathematical reasoning in writing.[8] Additionally, research from districts around the country show promise that the new standards may lead to higher levels of achievement. Kane and colleagues[9] found that students scored higher on CCSS-aligned math assessments in schools that provided more teacher professional development days and had higher percentages of teachers who felt knowledgeable about the standards, even when controlling for differences in prior student achievement and teacher effectiveness. Students also performed higher on math assessments when teachers received more frequent classroom

[6] The UChicago Consortium report also showed that the extensiveness of standards-related professional development (a measure of frequency and the number of topics covered in professional development) reported by teachers in a school corresponded to the level of instructional leadership in the school: teachers who worked in schools with strong instructional leaders reported significantly more extensive professional development than teachers in schools with weaker instructional leaders.
[7] Kane, Owens, Marinell, Thal, & Staiger (2016).
[8] Bay-Williams, Duffett, & Griffith (2016); Opfer, Kaufman, & Thompson (2016).
[9] Kane et al. (2016).

observations followed by explicit CCSS-related feedback and when teacher performance evaluations included student outcomes on standards-aligned achievement tests.

In the next sections, we examine whether implementation of the new standards led to similar improvements in CPS. Specifically, we examine whether reports about instructional experiences in math classes and also learning outcomes in math changed in schools with differing levels of standards-related professional development.

The Common Core State Standards for Mathematics

The new mathematics standards include two components: Standards for Mathematical Content and Standards for Mathematical Practice. The content standards identify the set of knowledge and skills that students should master at each grade level, while the practice standards describe a set of eight practices and mindsets that students should develop across all grade levels. The practice standards include:

- Make sense of problems and persevere in solving them
- Reason abstractly and quantitatively
- Construct viable arguments and critique the reasoning of others
- Model with mathematics
- Use appropriate tools strategically
- Attend to precision
- Look for and make use of structure
- Look for and express regularity in repeated reasoning[J]

The CCSS-M differ from most previous standards in three ways. First, they emphasize fewer topics at each grade level, allowing teachers to spend more time on each topic and expose students to content in a more in-depth and sustained manner. This shift was designed to address the "mile-wide inch-deep" quality that has typically characterized math instruction in this country and was intended to ensure that students have a strong foundation of mathematical concepts while also developing procedural fluency. The new standards are also linked across grade levels in a more coherent fashion. Concepts learned in each grade build on those in earlier grades. Lastly, the standards are intended to be rigorous in nature. They call for a deep understanding of key mathematical concepts, coupled with procedural skill and fluency and the ability to apply mathematical knowledge in situations that warrant it.[K]

[J] Common Core State Standards Initiative (2018b).
[K] Common Core State Standards Initiative (2018a).

Data and Methods

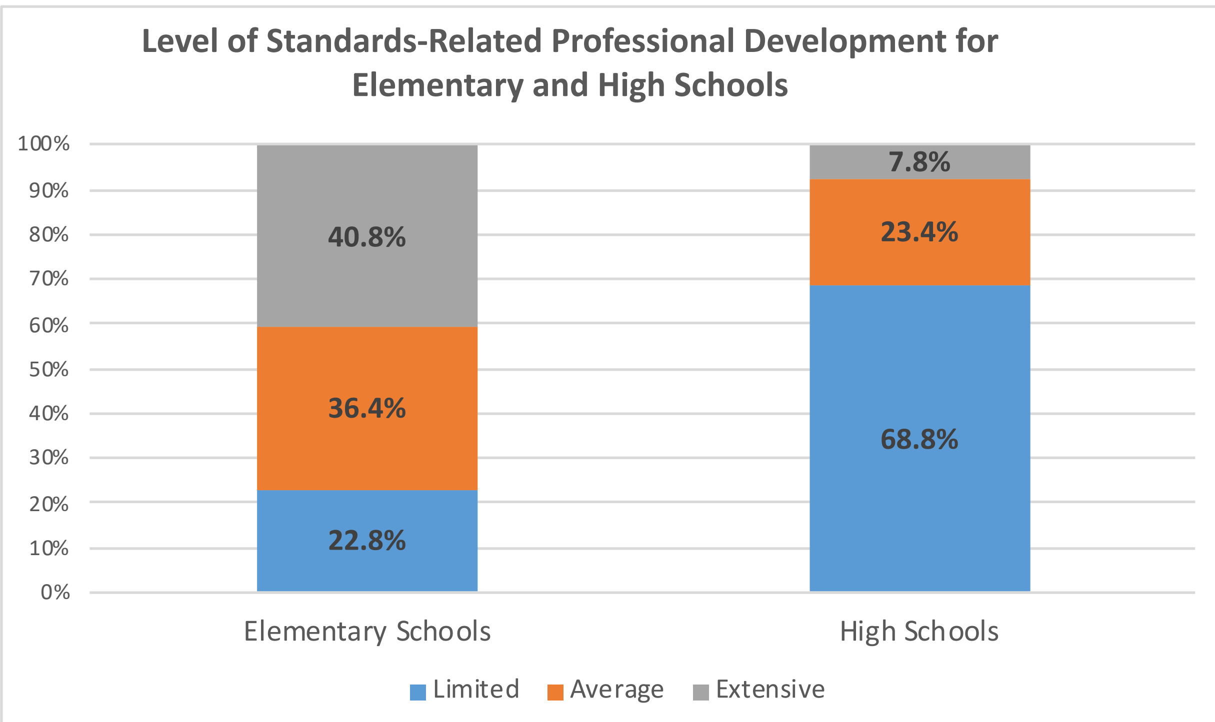
One of the most pressing concerns related to the implementation of the CCSS is whether teachers are able to adapt their instructional practice to realize the goals of the new standards. To assess whether this happened in CPS, we use student responses on the annual My Voice, My School student survey administered in the spring of each year from 2010-11 through 2016-17. Surveys were administered to all students in sixth through eighth grade and asked a series of questions about instructional experiences in math classes. We focus on three measures of instruction—academic demand, rigor, and instructional clarity—that might reasonably be expected to change given the shifts that the new math standards represent. Although the measures were not developed specifically to study the CCSS, they capture many of the aspects that the new math standards embody, particularly an emphasis on challenging material, real world problems, and the consideration of multiple solutions (see box entitled **The Common Core State Standards for Mathematics**). In addition to these three measures, we also include a measure of teacher support, since research has demonstrated the importance of support for making sure students remain engaged in their classes, particularly when they confront challenging academic material (see box entitled **Elements of Effective Classroom Instruction: Academic Demand and Teacher Support**). The items that comprise each measure are described in the box entitled **Measuring Students' Instructional Experiences in Mathematics Classrooms**.

We also examine whether students' math outcomes have improved since the implementation of the CCSS. For students in sixth through eighth grade, we analyze scores from the math portion of the NWEA from the spring of 2013 (the first year in which NWEA scores were administered in the district) through 2017. At the high school level, we analyze students' eleventh-grade math ACT scores from the spring of 2011 to the spring of 2016 (the last year the ACT was administered in Chicago). Additionally, we analyze math course grades and whether students passed their math course for students in sixth through twelfth grade from spring 2011 through spring 2017. Appendix A provides additional details about the data and sample.

We categorize schools in terms of their level of standards-related professional development in two ways, corresponding to the two components of the district's plan to support teachers in their transition to the new standards. First, we measure schools' participation in the districtwide professional learning program using a measure developed from the 2015 My Voice, My School teacher survey. Since teacher responses on the survey are anonymous and cannot be tied to individual students and classrooms, we aggregate their responses to the school level to capture a school-wide measure of standards-related professional development (see box entitled **Measuring Schools' Standards-Related Professional Development).** As shown in **Figure 1**, around 41 percent of elementary schools were classified as schools in which teachers reported extensive standards-related professional development, compared to only 8 percent of high schools. At the other end of the spectrum, only 23 percent of elementary schools were categorized as offering limited standards-related professional development compared to 69 percent of high schools.

Our second measure of schools' level of standards-related professional development captures the district strategy of providing more intensive support, beyond the districtwide workshop series, to a smaller group of schools in the form of coaching and participation in a professional learning community. In 2014-15, the district identified four networks of schools (Networks 1, 3, 4, and 6) where additional support would be provided, and schools within these four networks could elect to participate or not. A total of 87 schools (76 elementary schools and 11 high schools) received this additional support. This group of schools received this additional support through the end of the 2015-16 school year.

Figure 1. Classification of Elementary Schools and High Schools Based on Their Level of Standards-related Professional Development



Using a difference-in-difference (DID) estimation, we compare outcomes in schools with different levels of participation in the districtwide professional development program over three time periods: the pre-implementation period, which were the years before the district began preparing their teachers to implement the standards (2010-11 and 2011-12); the gearing up period, when the district was providing professional development but teachers were not expected to have fully incorporated all of the new standards into their teaching (2012-13 and 2013-14); and the early implementation period, when teachers were expected to have fully incorporated the new standards (2014-15, 2015-16 and 2016-17). This allows us, for example, to determine how similar schools with extensive standards-related professional development were to schools with limited standards-related professional development on a given outcome before the district began preparing for the new standards—and then assess whether this difference changed significantly by the gearing up period or by the early implementation period. If the initial, baseline difference on an outcome changes over time, particularly by the early implementation period, it suggests that the professional learning experiences of teachers in those schools may be related to that change. A similar set of comparisons is made for schools with average vs. limited levels of standards-related professional learning.

Separate analyses using the same analytic strategy compare outcomes in Deep Support schools to outcomes in non-Deep-Support schools. Analyses are run separately for students in sixth through eighth grade and for students in ninth through twelfth grade and control for students' background characteristics. Appendix A provides additional details about these analyses and shows the results from all statistical models.

Trends in CPS Students' Instructional Experiences

Districtwide Strategy: CPS students' reports about the quality of instructional experiences in their math classes have been improving over time (Panels A and B in **Figures 2-5**). Elementary students (Panel A) and high school students (Panel B) reported increasingly higher average levels of academic demand, rigor, instructional clarity, and also teacher support from the pre-implementation period (2010-11 and 2011-12) to the early implementation period (2014-15, 2015-16, and 2016-17) in schools with average, limited, and extensive professional development. At both the high school and elementary school levels, improvements were larger, and statistically significant, in schools with extensive professional development than in schools with limited professional development; however, patterns of improvement were different for elementary vs. high schools.

Among students in sixth through eighth grade, reports about the level of academic demand, rigor, clarity, and support were similar during the pre-implementation period in schools with limited vs. extensive standards-related professional development (and also in schools with average versus limited professional development; Panel A in **Figures 2-5**). By the early implementation period, improvements in all four instructional domains were significantly larger in schools where teachers reported extensive standards-related professional development than in schools with limited professional development, by about one-tenth of a standard deviation. This suggests that teachers in these schools may have been better positioned to change their practice in ways that were aligned with the goals of the new standards, creating more academically demanding and rigorous instructional environments, with greater instructional clarity and more support. Nevertheless, the improvements can be considered modest in nature.

Elementary schools with average levels of standards-related professional development also showed improvements in demand, rigor, clarity, and support, but these improvements were not significantly different from improvements in schools where teachers reported limited standards-related professional development.

Among high school students, improvements in rigor and teacher support were also significantly larger in schools where teachers reported extensive standards-related professional development than in schools where professional development was limited (Panel B in **Figures 2-5**). However, the patterns of improvement were different than in elementary schools. During the pre-implementation period, schools in which teachers would eventually report extensive standards-related professional development in 2015 started out with significantly lower levels of rigor and teacher support than schools with limited professional development, but by the early implementation period they had caught up and closed the gap. It's worth noting that improvements among high schools with extensive professional development were larger than among elementary schools with the same level of professional development: 0.15 standard deviations compared to approximately 0.10.

Measuring Schools' Standards-Related Professional Development

In 2014 and 2015, the My Voice, My School teacher survey included a number of questions asking teachers about their experiences preparing for the new standards. Several items asked teachers to describe their professional development related to the new standards, including how frequently they participated in standards-related professional development and which topics were covered in these sessions. These items, described below, were combined into a single measure, using Rasch analysis, which captures the extensiveness of standards-related professional development. Teachers' scores on this measure were then aggregated to the school level and schools were categorized into one of three groups. Schools that fell into the top third of the distribution were identified as schools with extensive standards-related professional development, schools in the middle third were identified as schools with average levels of standards-related professional development, and schools in the bottom third were identified as having limited standards-related professional development.

Items Included in the Extensiveness of Standards-Related Professional Development Measure

- How often did you receive formal training or professional development on CCSS this past year? (*Never, Once this year, Once or Twice a semester, Monthly, Weekly*)
- Which of the following topics have been addressed in your CCSS training and professional development? *Check all that apply.*
    - ○ Common Standards in English/Language Arts and Literacy
    - ○ Common Standards in Mathematics
    - ○ Curriculum materials and resources to teach the common standards
    - ○ Teaching common standards to specific student groups (for example, students with disabilities or English Language Learners)
    - ○ Adapting classroom assessments to the common standards
    - ○ New standardized assessments aligned with CCSS
    - ○ Research on best practices for implementation of the common standards

As for academic demand and instructional clarity, these elements of instruction also improved in high schools, but improvements in schools with extensive professional development were comparable to those in schools with limited professional development. For schools where teachers reported average levels of standards-related professional development in 2015, improvements over time in all four instructional domains were not statistically different from those in schools with limited professional development.

The fact that both elementary and high schools where teachers reported limited standards-related professional development also showed improvement in instruction over time raises the question of what may have been driving these improvements. Given that our measure of standards-related professional development at the school level only captures what was happening in schools in a single year, it's possible that schools that offered limited professional development in 2015 offered more standards-related training in subsequent years. It's also possible that other district policies—for example, the new teacher evaluation system—also played a role in improving instructional practice in the district.

Figure 2. Trends in Students' Reports about Academic Demand in Math Classes, by Level of Standards-related Professional Development

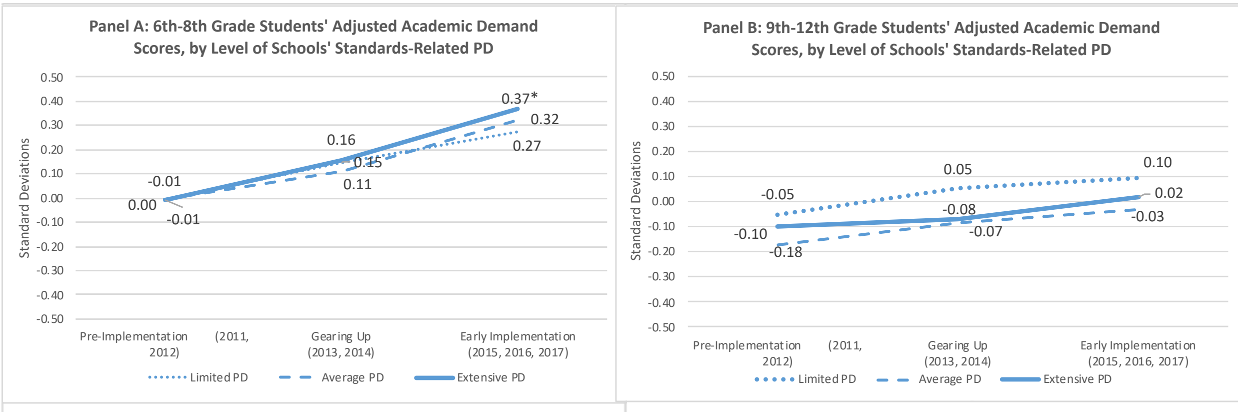


Figure 3. Trends in Students' Reports about Rigor in Math Classes, by Level of Standards-related Professional Development

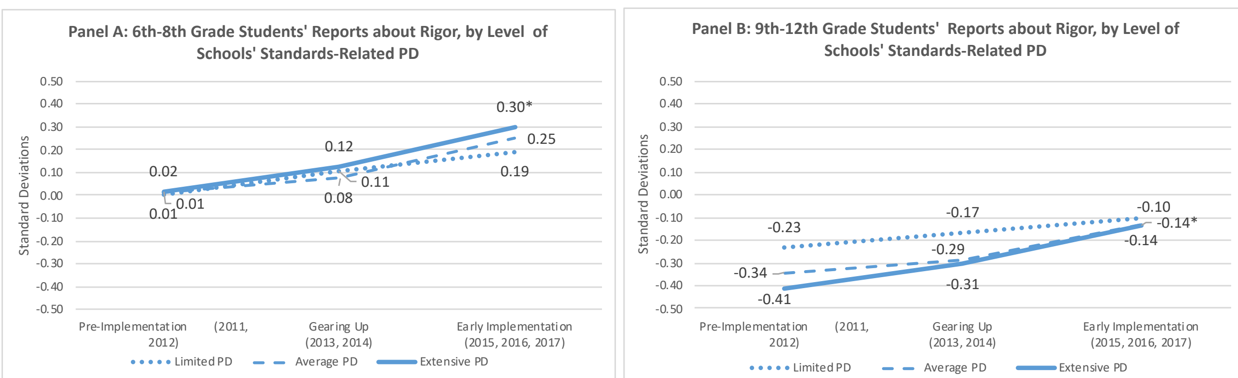


Figure 4. Trends in Students' Reports about Instructional Clarity in Math Classes, by Level of Standards-related Professional Development

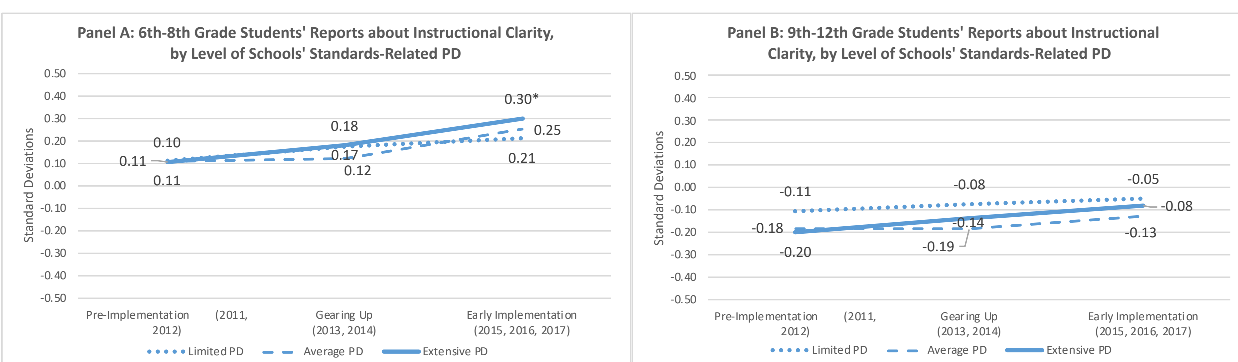
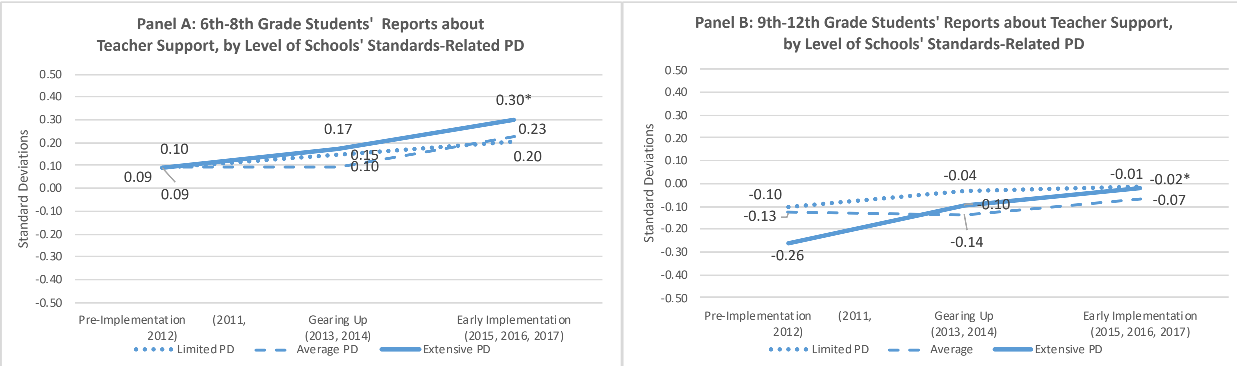


Figure 5. Trends in Students' Reports about Teacher Support in Math Classes, by Level of Standards-related Professional Development



Note: The years shown in each time period on the horizontal axis are the spring term for that school year. Average scores for each measure of instruction across all three time periods come from a three-level hierarchical linear model in which students were nested within years and then within schools. The level-1 model takes into account students' grade level, background characteristics, prior math scores, and type of math class taken at the time the survey was administered. The level-2 model includes dummy variables for two time periods: the gearing-up years (2013, 2014) and early-implementation years (2014-15, 2015-16, and 2016-17), with the pre-implementation period as the omitted category. The level-3 model includes two dummy variables identifying whether schools had extensive or average standards-related professional development, as reported by teachers; schools with limited professional development were the omitted category.
* indicates that the difference-in-difference (DID) estimation is significant at the 0.05 level.

Deep Support Schools: We also examined whether improvements in math instruction differed for students enrolled in "Deep Support" schools—schools that received additional standards-related support in the form of professional learning communities and coaching—compared to students in schools that did not receive this kind of support. Among students in sixth through eighth grade, reports about the level of academic demand, rigor, clarity, and teacher support were comparable during the pre-implementation in Deep Support and non-Deep-Support schools. Over time, reports about the quality of math instruction improved in both types of schools; however, improvements in academic demand and teacher support were larger and statistically significant in non-Deep-Support schools, although the differences were small, around 0.05 standard deviations. Improvements in rigor and instructional clarity were similar for both groups of schools (see Panel A in **Figures A.1-A.4 in Appendix A**).

At the high school level, reports about instruction started out somewhat lower in Deep Support schools during the pre-implementation years. Although reports improved over time, they did so at rates that were comparable to non-Deep-Support schools (see Panel B in **Figures A.1- A.4 in Appendix A**).

Trends in Math Test Scores from 2010-2011 to 2016-17

Districtwide Strategy: A principal aim of the CCSS is to promote higher levels of student achievement through exposure to more demanding skills that are coherently aligned over time. Teachers who have access to more extensive professional learning related to the new standards should be better positioned to ensure their teaching is aligned with the goals of the new standards. The previous section confirmed this, at least at the elementary school level: among sixth through eighth grade students, those enrolled in schools where teachers reported extensive standards-related professional development reported significantly larger increases in the level of academic demand in their math classes by the early implementation period. At the high school level, however, increases in the level of academic demand were similar across schools, regardless of the level of standards-related professional development. Given these findings, we examine whether there were differences in students' math test scores over time, based on the level of professional learning reported by teachers in their schools.

On average, NWEA math test scores of students in sixth through eighth grade increased over time, from the gearing-up period to the early implementation period, across all three groups of schools (Panel A in **Figure 6)**.[10] Increases in scores were larger, and statistically different, in schools where teachers reported extensive standards-related professional development compared to schools where professional development was limited, although the increase was fairly modest in nature.[11]

Since challenging instruction has consistently been shown to lead to higher test scores, we examined whether higher levels of academic demand in the early implementation period for schools with extensive standards-related professional development might be associated with larger increases in tests scores in these schools during the same time. Indeed, taking into account schools' level of academic demand during the early implementation period did account for a portion of the higher rates of improvement in test scores of students in schools where teachers reported more extensive professional development.[12]

Average math NWEA scores of students in schools where teachers reported only average levels of standards-related professional development also improved over time, but at a rate that was comparable to scores of students in schools with limited professional development.

Panel B in **Figure 6** shows trends in average ACT scores for eleventh-grade students over the three time periods. Changes in ACT scores were similar for schools with extensive, average and limited professional development. This is not all together surprising given the findings in the previous section, which showed that academic demand increased at comparable rates over time for all three groups of schools.

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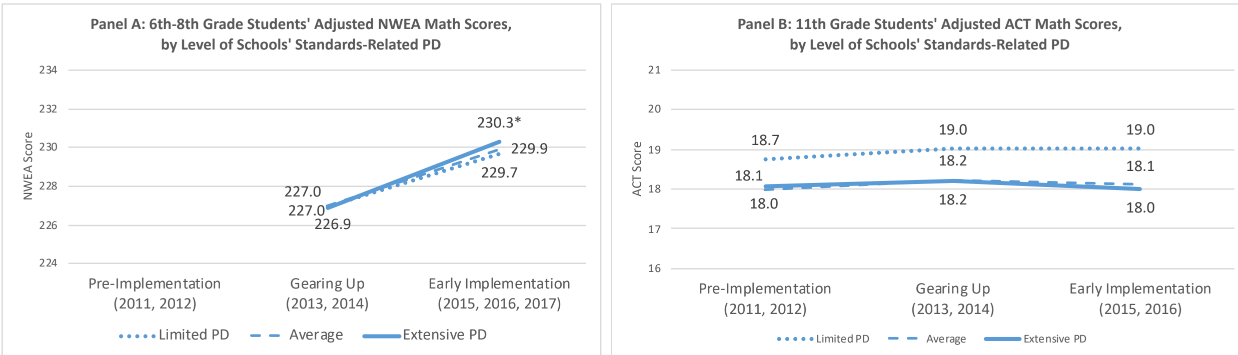
[10] Because the NWEA was not administered in CPS prior to the 2012-13 school year, we use a modified version of the analytic model in which we analyze trends from the gearing-up period (2012-13, 2013-14) to the post-implementation period (2014-15, 2015-16, 2016-17).
[11] The DID estimation comparing schools with extensive professional development to schools with limited professional development in the early implementation period was 0.70 or about 0.04 standard deviations.
[12] The DID estimator comparing tests scores between students in schools where teachers reported extensive standards-related professional development and students in schools where teachers reported limited professional development went from 0.70 to 0.54 and was no longer significant.

Figure 6. Trends in Students' Math Test Scores, by Schools' Level of Standards-related Professional Development



Note: The years shown in each time period on the horizontal axis are the spring term for that school year. Average NWEA and ACT math test scores in each time period come from 3-level hierarchical linear models in which students were nested within years and then within schools. The level-1 model for both NWEA scores and ACT scores takes into account students' grade level (NWEA only), background characteristics, prior math scores, and type of math class taken during the spring semester, when the test was administered. The level-2 model for NWEA scores includes a dummy variable for the early-implementation years (2014-15, 2015-16, and 2016-17), with the gearing-up period as the omitted category. The level-2 model for ACT scores includes dummy variables for both the gearing-up years (2013, 2014) and the early-implementation years (2014-15 and 2015-16), with the pre-implementation period serving as the omitted category. The level-3 model includes two dummy variables identifying whether schools had extensive or average standards-related professional development, as reported by teachers; schools with limited professional development were the omitted category.
* indicates that the DID estimation is significant at the 0.05 level.

Deep Support Schools: As for Deep Support schools, the previous section showed that, among elementary students, improvements in academic demand were somewhat smaller in Deep Support schools than in non-Deep-Support schools, although the differences were quite small. At the high school level, improvements in academic demand were comparable in Deep Support and non-Deep-Support schools. Collectively, these findings suggest that we might not expect to see much difference in test score improvements between the two groups of schools. And yet, as shown in **Figure A.5 in Appendix A**, both NWEA scores and ACT scores improved significantly more in Deep support Schools than in non-Deep-Support schools, although, again, the differences were quite small.

Trends in Course Performance from 2010-2011 to 2016-17

Districtwide Strategy: Demanding classes can lead to higher levels of student achievement, but they can also result in disengagement if teachers fail to provide strong academic support to help students as they confront challenging material. In the previous section, we saw that while schools with extensive standards-related professional development reported significantly higher levels of academic demand in the early implementation period, at least at the elementary level, they also reported high levels of teacher support, which may have served as a critical lever for helping students remain engaged even as classroom environment became more challenging. At the high-school level, teacher support also increased significantly more in schools with extensive standards-related professional development.

To assess whether the implementation of CCSS-M had any negative impact on students' math course performance, we examine trends over time in math course grades and math course passing rates. Overall, math grades improved over time and at similar rates for students in sixth through twelfth grade in schools with differing levels of standards-related professional development (Panels A and B in **Figure 7**).

For both elementary and high school students, higher course grades seem to be driven in part by more students passing their math classes over time, as shown in Panels A and B of **Figure 8**. Among elementary schools, improvements in passing rates were significantly higher in schools with extensive standards-related professional development compared to schools with limited professional development, which is noteworthy given the higher levels of academic demand that was also evident in these schools. At the high-school level, improvements over time in pass rates were comparable for differing levels of standards-related professional development.

Figure 7. Trends in Students' Average Math Grades, by Level of Schools' Standards-related Professional Development

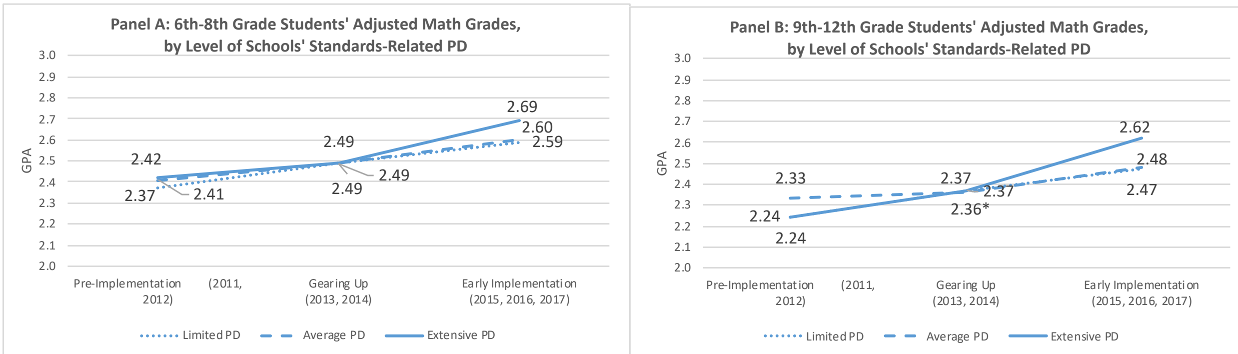
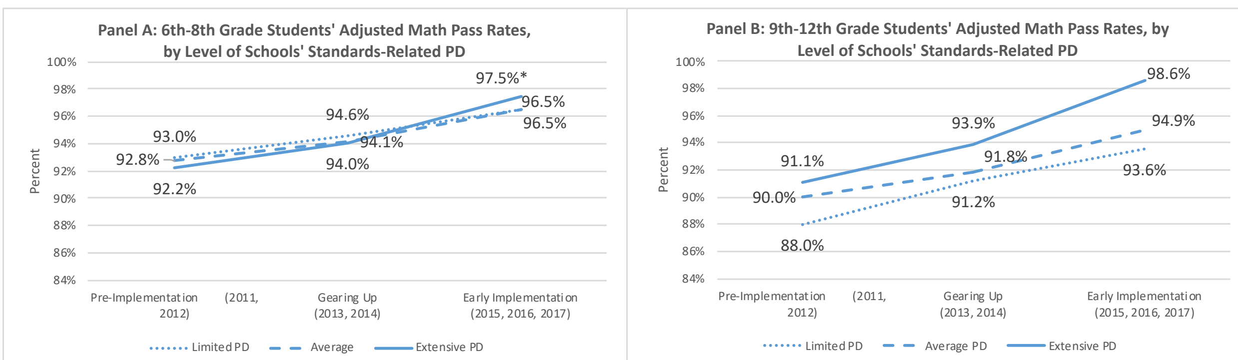


Figure 8. Trends in Students' Average Passing Rates for Math Classes, by Level of Schools' Standards-related Professional Development



Note: The years shown in each time period on the horizontal axis are the spring term for that school year. Average math grades and pass rates in each time period come from 3-level hierarchical linear models in which students were nested within years and then within schools. The level-1 model takes into account students' grade level, background characteristics, prior math scores, and type of math class taken during the spring semester. The level-2 model includes dummy variables for both the gearing-up years (2013, 2014) and the early-implementation years (2014-15, 2015-16, and 2016-17), with the pre-implementation period serving as the omitted category. The level-3 model includes two dummy variables identifying whether schools had extensive or average standards-related professional development, as reported by teachers; schools with limited professional development were the omitted category.
* indicates that the DID estimation is significant at the 0.05 level.

Deep Support Schools: The previous section showed that among sixth through eighth grade students, reports about levels of teacher support showed somewhat smaller increases in Deep Support schools by the early implementation period than in non-Deep-Support schools. Possibly related to these smaller increases in teacher support are smaller improvements in math course grades and math passing rates in Deep Support schools compared to non-Deep-Support schools, as shown in **Figures A.6 and A.7 in Appendix A.** At the high-school level, improvements in math grades and pass rates were similar in Deep Support and non-Deep-Support schools.

Summary

Transitioning to the CCSS has involved a significant investment in both time and resources for CPS. To ensure that math instruction was aligned with the goals of the new standards, the Department of Mathematics developed a professional learning program emphasizing high-quality math instruction that was first launched in 2012-13 and still continues today. The initiative had two components: 1) a districtwide strategy that offered professional development through workshops focused on high-quality math instruction; and 2) more targeted support to a smaller group of schools in select networks—"Deep Support" schools—that included participation in a professional learning community and, in some cases, instructional coaching, in addition to the workshops offered to all schools.

Evidence from this study suggests that the districtwide strategy supporting teachers' transition to the new standards may be paying off. Since the district first began offering professional development related to the new standards, students' instructional experiences in their math classes, as measured by survey reports, improved most substantially in schools where teachers reported extensive standards-related professional development. For elementary schools serving sixth- through eighth–grade students, this meant that by the early implementation period, students in these schools reported significantly higher levels of academic demand, rigor, instructional clarity, and teacher support than students in schools where teachers reported limited professional development. Among high school students, schools with extensive standards-related professional development were able to close a preexisting gap by the early implementation period in the level of rigor, and teacher support—although not academic demand—between themselves and schools with limited standards related professional development.

Significant but modest improvements in math test scores among sixth- through eighth-grade students were also evident by the early implementation period in schools where teachers reported more extensive standards-related instruction, compared to schools where professional development was more limited. Increases in test scores were in part related to the higher levels of demand reported in math classes in schools with extensive professional development. Among eleventh-grade students, however, changes in ACT scores were similar across schools, regardless of their level of standards-related professional development, echoing the fact that academic demand increased at similar rates for these schools.

Although previous efforts by CPS to increase the level of academic demand in math classes resulted in more course failures,[13] this does not appear to be the case with the transition to the new math standards. Instead, we find that average course grades and pass rates have improved since the transition to the CCSS, even in elementary schools that offered more extensive standards-related professional development and where academic demand in math increased most significantly. Moreover, pass rates were significantly higher by the early implementation period in schools with extensive professional development.

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13 Allensworth, Nomi, Montgomery, & Lee (2009).

As for the Deep Support schools, evidence from this study is somewhat mixed. Improvements in academic demand and teacher supports were not as large in Deep Support schools as in non-Deep Support schools, although the differences were small. In terms of student outcomes, test scores, improved at significantly higher rates for elementary and high school students in Deep Support schools (although the differences were small), but improvements in grades, at least at the elementary level, were not as large in these schools. The findings suggest that the nature of professional development that occurred in professional learning communities, and in some instances, instructional coaching, was more effective for improving test scores rather than grades.

When considering the implications of this study's findings, it's important to keep in mind that the study looks for change only three years after teachers were expected to have fully transitioned to the new math standards. The significantly larger improvements in both instruction and student outcomes in schools with more extensive implementation of the districtwide plan may be considered modest in nature. But given the relatively short window for an intervention of this magnitude, the results show promise for the district's strategy to support teachers in their transition to the new standards. Nevertheless, it's important not to lose sight of the fact that only a portion of schools and teachers in the district received the professional learning they needed to successfully enact change in instruction and student outcomes. At the elementary level, around 40 percent of schools were identified as such, but at the high school level fewer than 10 percent were identified as having extensive standards-related professional development. Nearly two-thirds of high schools were identified as having limited standards-related professional development. As CPS and other districts around the country continue to work toward making sure instructional practice is aligned with the goals of the new standards, considering how to ensure that all teachers have access to high-quality standards-related professional development will be important.

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Appendix A:

Data, Sample, Methods and Statistical Results

Sample and Data

This study is based on CPS students who were in sixth through twelfth grades at any point from 2010-11 to 2016-17, who had a math test score from the previous school year, and who were enrolled in a regular CPS school. Regular CPS schools include neighborhood schools, magnet schools, selective schools, and charter schools; however, as described below, charter schools are omitted from analyses of course grades and course passing rates because we do not have access to their transcript data. Regular CPS schools do not include alternative schools or special education schools.

Data for analyses came from two sources: Administrative records and annual student and teacher surveys. Administrative records include information about students' background characteristics (e.g., race/ethnicity, gender, special education status, and address), test scores, course enrollment, and course performance for all students enrolled in the district each year since 1991. Although administrative records include background and test score data for students enrolled in charter schools, they do not include information about their course enrollment or course performance; as a result, analyses using these data do not include charter school students.

Surveys are administered each year to all CPS teachers and to students in sixth through twelfth grade. On the student survey, students are randomly assigned to answer a series of questions about either their math, ELA, or science class. Only students who responded to questions about their math classes on surveys administered in the spring of 2011 through 2017 are included in these analyses. Student survey response rates range from 74 percent to 83 percent during these years. Rasch analysis was used to combine items into measures of instructional experiences, including academic demand, rigor, instructional clarity, and teacher supports.

Teacher responses to items from the 2015 teacher survey were used to classify schools according to the level of standards related professional development they offered (see the box entitled **Measuring Schools' Standards-Related Professional Development**). Rasch analysis was also used to combine teacher survey responses on these items to create a measure of the extensiveness of mathematics standards-related professional development. Tables A.1 through A.6 report sample sizes for each analysis.

Methods

We use a DID estimation within a 3-level HLM model to compare changes over time in students' instructional experiences and learning outcomes in mathematics in schools with differing levels of standards-related professional development. Models nest students (level 1) within years (level 2) and schools (level 3). The level-1 model includes student background characteristics A (race, gender, neighborhood poverty level, neighborhood socioeconomic status, special education status), students' prior year's math test scores X, and the type of math class they were enrolled in at the time the survey was administered, S. At level-2, the model includes dummy variables indicating whether the year was during the gearing up period (2012-13, 2013-14), or the early implementation period (2014-15, 2015-16, 2016-17), with the pre-implementation period (2010-11, 2011-12) as the omitted category. Level-3 includes dummy variables for schools with average and extensive levels of standards-related professional learning, as reported by teachers, and schools with limited professional development as the omitted category.

Level-1 Model

$$Y_{ijk} = \pi_{0jk} + \pi_{1jk}(A_{ijk}) + \pi_{2jk}(X_{ijk}) + \pi_{3jk}(S_{ijk}) + e_{ijk}$$

Level-2 Model

$$\pi_0 jk = \beta_{00k} + \beta_{01k}(\text{GearUp}_{jk}) + \beta_{02k}(\text{EarlyImp}_{jk}) + r_{0jk}$$

$$\pi_{1jk} = \beta_{10k}$$

$$\pi_{2jk} = \beta_{20k}$$

$$\pi_{3jk} = \beta_{30k}$$

Level-3 Model for District-wide professional learning models

$$\beta_{00k} = \gamma_{000} + \gamma_{001}(\textit{Average standards-related PD}_k) + \gamma_{002}(\textit{Extensive standards-related PD}_k) + u_{00k}$$

$$\beta_{01k} = \gamma_{010} + \gamma_{011}(\textit{Average standards-related PD}_k) + \gamma_{012}(\textit{Extensive standards-related PD}_k) + u_{01k}$$

$$\beta_{02k} = \gamma_{020} + \gamma_{021}(\textit{Average standards-related PD}_k) + \gamma_{022}(\textit{Extensive standards-related PD}_k) + u_{02k}$$

$$\beta_{10k} = \gamma_{100}$$

$$\beta_{20k} = \gamma_{200}$$

$$\beta_{30k} = \gamma_{300}$$

Level-3 Model for Deep Support schools

$$\beta_{00k} = \gamma_{000} + \gamma_{001}(DeepSupport_k) + u_{00k}$$
$$\beta_{01k} = \gamma_{010} + \gamma_{011}(DeepSupport_k) + u_{01k}$$
$$\beta_{02k} = \gamma_{020} + \gamma_{021}(DeepSupport_k) + u_{02k}$$
$$\beta_{10k} = \gamma_{100}$$
$$\beta_{20k} = \gamma_{200}$$
$$\beta_{30k} = \gamma_{300}$$

Tables A.1-A.6 show results from each statistical analysis included in this study. For the sake of parsimony, we only show coefficients from the level-3 portion of the model.

Table A.1. Level 3 Coefficients from HLM Models Examining Trends in Students' Reports about Instructional Experiences, by Schools' Level of Standard-related Professional Development

	Academic Press		Rigor		Instructional Clarity		Teacher Support	
	6th-8th	9th-12th	6th-8th	9th-12th	6th-8th	9th-12th	6th-8th	9th-12th
Intercept								
Intercept	-0.007	-0.051	0.006	-0.232 ***	0.107 ***	-0.105 ***	0.090 **	-0.102 ***
AveragePD	0.003	-0.124 *	0.007	-0.110 *	0.000	-0.077 ~	0.005	-0.024
ExtensivePD	-0.004	-0.050	0.012	-0.178 **	-0.003	-0.096 *	0.003	-0.157 *
GearUp								
Intercept	0.156 ***	0.101 ***	0.103 **	0.066 **	0.066 **	0.030	0.059 **	0.067 **
AveragePD	-0.040	-0.008	-0.041	-0.011	-0.055	-0.034	-0.059	-0.076 *
ExtensivePD	0.013	-0.070	0.002	0.038	0.010	0.036	0.020	0.096
EarlyImp								
Intercept	0.281 ***	0.147 ***	0.185 ***	0.128 ***	0.103 ***	0.057 **	0.113 ***	0.090 ***
AveragePD	0.045	-0.003	0.051	0.015	0.039	-0.001	0.022	-0.033
ExtensivePD	0.098 *	-0.030	0.095 *	0.147 *	0.092 **	0.062	0.094 *	0.151 *
N Students	173,057	148,848	173,383	149,338	171,607	147,739	170,989	147,321
N Schools	483	143	483	143	483	143	483	143

Note: * indicates significance at the 0.05 level, ** at the .01 level, *** at the .001 level.

Table A.2. Level 3 Coefficients from HLM Models Examining Trends in Reports about Instructional Experiences, by Schools' Deep Support Status

	Academic Press		Rigor		Instructional Clarity		Teacher Support	
	6th-8th Grade	9th-12th Grade	6th-8th Grade	9th-12th Grade	6th-8th Grade	9th-12th Grade	6th-8th Grade	9th-12th Grade
Intercept								
Intercept	-0.010	-0.076 **	0.012	-0.269 ***	0.107 ***	-0.123 ***	0.095 ***	-0.116 ***
DeepSupport	0.014	-0.101 ~	0.008	-0.029	-0.006	-0.090	-0.014	-0.040
GearUp								
Intercept	0.143 ***	0.096 ***	0.078 ***	0.071 ***	0.048 ***	0.029	0.043 ***	0.062 ***
DeepSupport	0.018	-0.025	0.058	-0.069	0.004	-0.054	0.011	-0.084
EarlyImp								
Intercept	0.348 ***	0.145 ***	0.246 ***	0.143 ***	0.163 ***	0.062 ***	0.170 ***	0.094 ***
DeepSupport	-0.067 ~	-0.012	-0.029	-0.004	-0.055	-0.003	-0.068 ~	-0.018
N Students	173,057	148,848	173,383	149,338	171,607	147,739	170,989	147,321
N Schools	483	143	483	143	483	143	483	143

Note: ~ indicates significance at the .10 level, * at the 0.05 level, ** at the .01 level, *** at the .001 level.

Table A.3. Level 3 Coefficients from HLM Models Examining Trends in Students' Test Scores, by Schools' Level of Standards-related Professional Development

	Test Scores	
	NWEA 6th-8th Grade	ACT 11th Grade
Intercept		
Intercept		18.74 ***
AveragePD		-0.76 **
ExtensivePD		-0.67 **
GearUp		
Intercept	226.97 ***	0.28 ***
AveragePD	0.03	-0.02
ExtensivePD	-0.11	-0.13
EarlyImp		
Intercept	2.71 ***	0.27 **
AveragePD	0.23	-0.14
ExtensivePD	0.70 *	-0.33
N Students	361,100	122,129
N Schools	478	139

Note: * indicates significance at the 0.05 level, ** at the .01 level, *** at the .001 level

Table A.4. Level 3 Coefficients from HLM Models Examining Trends in Students' Test Scores, by Schools' Deep Support Status

	Test Scores	
	NWEA 6th-8th Grade	ACT 11th Grade
Intercept		
Intercept		18.53 ***
DeepSupport		-0.22
GearUp		
Intercept	226.92 ***	0.24 ***
DeepSupport	0.07	0.29 *
EarlyImp		
Intercept	2.98 ***	0.18 **
DeepSupport	0.50 *	0.32 *
N Students	361,100	122,129
N Schools	478	139

Note: * indicates significance at the 0.05 level, ** at the .01 level, *** at the .001 level.

Table A.5. Level 3 Coefficients from HLM Models Examining Trends in Math Course Grades and Math Pass Rates, by Level of Standards-related Professional Development

	Math GPA		Math Pass Rates	
	6th-8th Grade	9th-12th Grade	6th-8th Grade	9th-12th Grade
Intercept				
Intercept	2.37 ***	2.24 ***	0.930 ***	0.880 ***
AveragePD	0.04	0.09	-0.002	0.020
ExtensivePD	0.05	0.00	-0.008	0.031
GearUp				
Intercept	0.12 ***	0.13 ***	0.016 **	0.032 ***
AveragePD	-0.04	-0.10 *	-0.003	-0.014
ExtensivePD	-0.05	0.00	0.002	-0.004
EarlyImp				
Intercept	0.22 ***	0.23 ***	0.035 ***	0.056 ***
AveragePD	-0.03	-0.08	0.002	-0.007
ExtensivePD	0.05	0.15	0.018 *	0.019
N Students	464,073	977,849	464,172	977,849
N Schools	418	123	418	123

Note: * indicates significance at the 0.05 level, ** at the .01 level, *** at the .001 level.

Table A.6. Level 3 Coefficients from HLM Models Examining Trends in Math Course Grades and Math Pass Rates, by Deep Support Status

	Math Grades		Math Pass Rates	
	6th-8th Grade	9th-12th Grade	6th-8th Grade	9th-12th Grade
Intercept				
Intercept	2.41 ***	2.31 **	0.923 ***	0.896 ***
DeepSupport	-0.02	-0.19 *	0.014	-0.038 *
GearUp				
Intercept	0.09 ***	0.10 ***	0.017 ***	0.028 ***
DeepSupport	0.01	0.04	-0.008	-0.002
EarlyImp				
Intercept	0.25 ***	0.20 ***	0.047 ***	0.056 ***
DeepSupport	-0.09 *	0.05	-0.025 ***	0.002
N Students	464,073	977,849	464,172	977,849
N Schools	418	123	418	123

Note: * indicates significance at the 0.05 level, ** at the .01 level, *** at the .001 level.

Figure A.1. Trends in Students' Reports about Academic Demand in Math Classes, by Schools' Deep Support Status

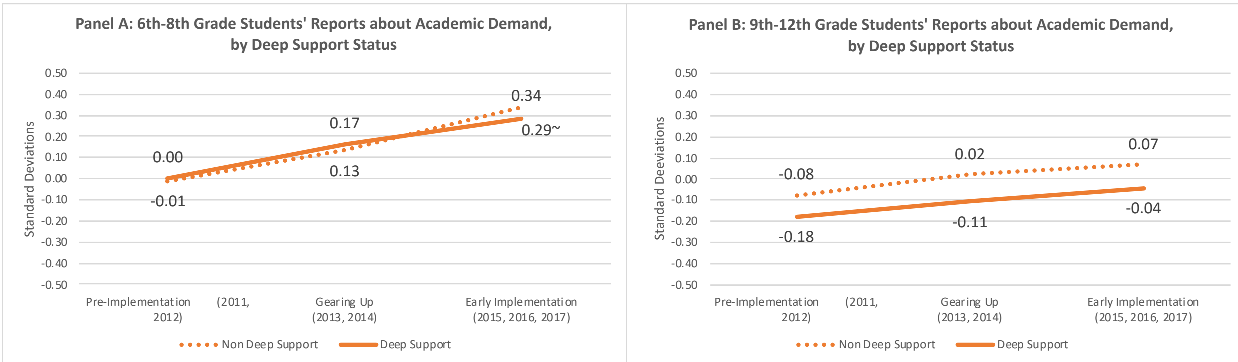


Figure A.2. Trends in Students' Reports about Rigor in Math Classes, by Schools' Deep Support Status

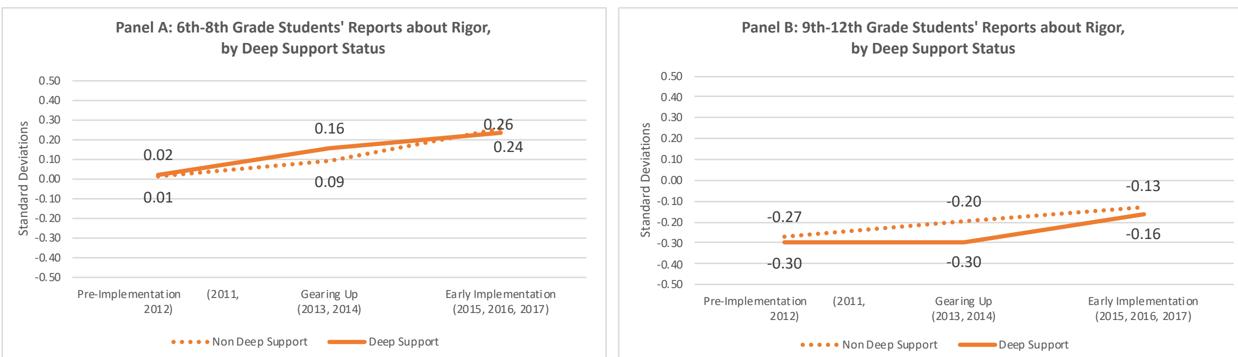


Figure A.3. Trends in Students' Reports about Instructional Clarity in Math Classes, by Schools' Deep Support Status

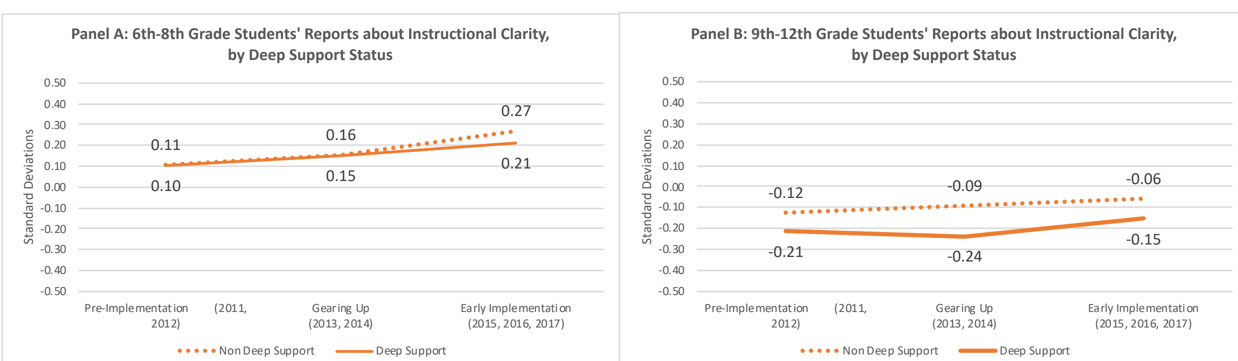
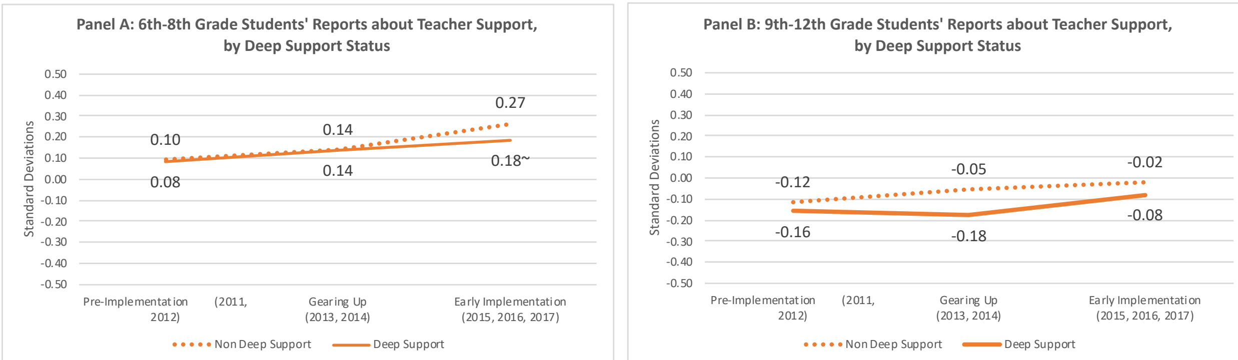
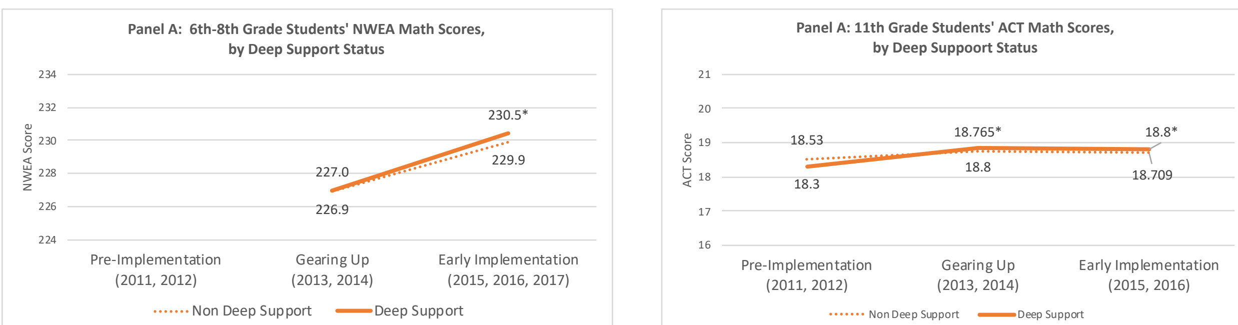


Figure A.4. Trends in Students' Reports about Teacher Support in Math Classes, by Schools' Deep Support Status



Note for Figures A.1.-A.4.: The years shown in each time period on the horizontal axis are the spring term for that school year. Average scores for each measure of instruction across all three time periods come from a three-level hierarchical linear model in which students were nested within years and then within schools. The level-1 model takes into account students' grade level, background characteristics, prior math scores, and type of math class taken at the time the survey was administered. The level-2 model includes dummy variables for two time periods: the gearing-up years (2013, 2014) and early-implementation years (2014-15, 2015-16, and 2016-17). The pre-implementation period is the omitted category. The level-3 model includes a dummy variable identifying Deep Support schools.
~ indicates that the difference-in-difference (DID) estimation is significant at the 0.10 level.

Figure A.5 Trends in Students' Math Test Scores, by Schools' Deep Support Status



Note: The years shown in each time period on the horizontal axis are the spring term for that school year. Average NWEA and ACT math test scores in each time period come from 3-level hierarchical linear models in which students were nested within years and then within schools. The level-1 model for both NWEA scores and ACT scores takes into account students' grade level (NWEA only), background characteristics, prior math scores, and type of math class taken during the spring semester, when the test was administered. The level-2 model for NWEA scores includes a dummy variable for the early-implementation years (2014-15, 2015-16, and 2016-17), with the gearing-up period as the omitted category. The level-2 model for ACT scores includes dummy variables for both the gearing-up years (2013, 2014) and the early-implementation years (2014-15 and 2015-16), with the pre-implementation period serving as the omitted category. The level-3 models include a dummy variable identifying Deep Support schools.
* indicates that the DID estimation is significant at the 0.05 level.

Figure A.6. Trends in Students' Math Course Grades, by Schools' Deep Support Status

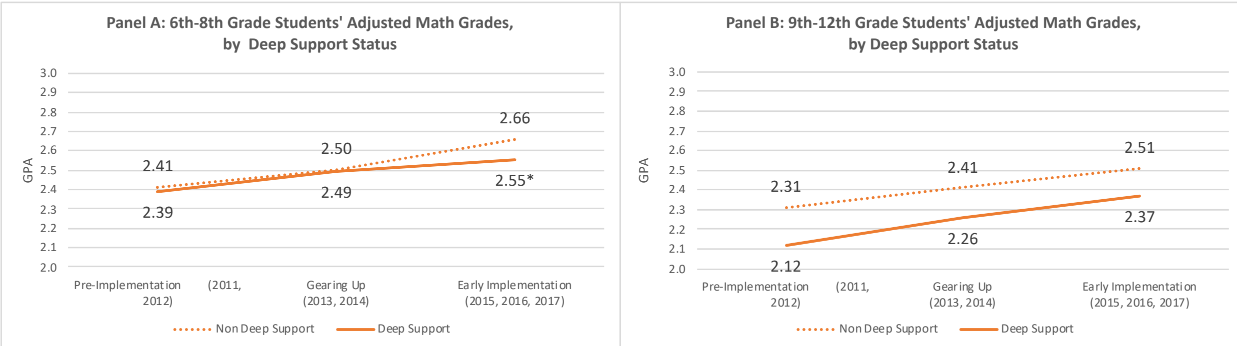
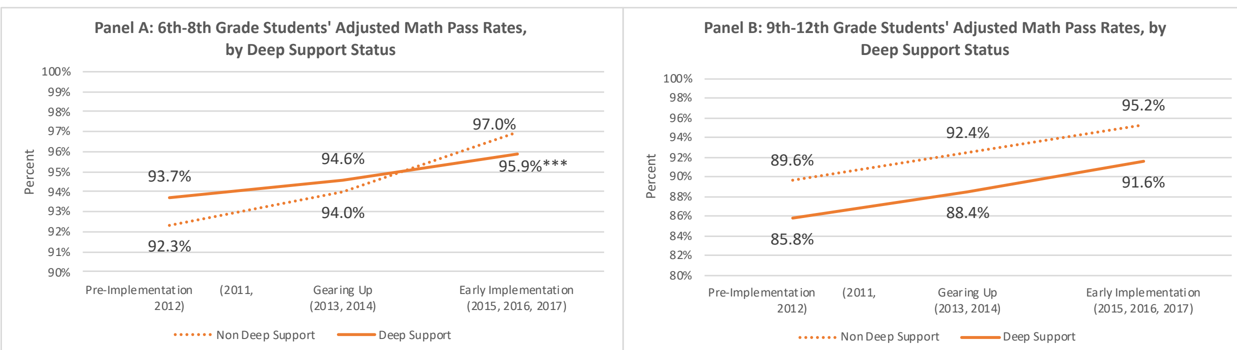


Figure A.7. Trends in Students' Pass Rates in Math Classes, by Schools' Deep Support Status



Note for Figures A.6.-A.7.: The years shown in each time period on the horizontal axes are the spring term for that school year. Average math grades and pass rates in each time period come from 3-level hierarchical linear models in which students were nested within years and then within schools. The level-1 model takes into account students' grade level, background characteristics, prior math scores, and type of math class taken during the spring semester. The level-2 model includes dummy variables for both the gearing-up years (2013, 2014) and the early-implementation years (2014-15, 2015-16, and 2016-17), with the pre-implementation period serving as the omitted category. The level-3 model includes a dummy variable identifying Deep Support schools.
* indicates that the DID estimation is significant at the 0.05 level; *** indicates significance at the .001 level.

Appendix B

Each year CPS administers the *My Voice, My School* survey to all CPS teachers and to students in sixth through twelfth grade. A portion of the student survey asks students to describe their instructional experiences in their math, ELA, or science classes. Students' responses to individual items are combined using Rasch analysis to create measures capturing different aspects of their instructional experience. Items comprising each of the four measures used in these analyses are shown below.

Table B.1. Measuring Students' Instructional Experiences in their Mathematics Classes

Academic Demand:

- This class really makes me think.
- I'm really learning a lot in this class.
- In my class, my teacher:
  - Expects everyone to work hard.
  - Expects me to do my best all the time.
  - Wants us to become better thinkers, not just memorize things.
- In your class, how often:
  - Are you challenged?
  - Do you have to work hard to do well?
  - Does the teacher ask difficult questions on tests?
  - Does the teacher ask difficult questions in class?

Rigor:

- My teacher:
  - Often connects what I am learning to life outside of the classroom.
  - Encourages students to share their ideas about things we are studying in class.
  - Often requires me to explain my answers.
  - Encourages us to consider different solutions or points of view.
  - Doesn't let students give up when the work gets hard.
- In my class, we talk about different solutions or points of view.

Instructional clarity:

- I learn a lot from feedback on my work.
- It's clear to me what I need to do to get a good grade.
- The work we do in class is good preparation for the test.
- The homework assignments help me to learn the course material.
- I know what my teacher wants me to learn in this class.

Teacher Support:

- The teacher for this class:
  - Helps me catch up if I am behind.
  - Is willing to give extra help on schoolwork if I need it.
  - Notices if I have trouble learning something.
  - Gives me specific suggestions about how I can improve my work in this class.
  - Explains things in a different way if I don't understand something in class.

ABOUT THE AUTHORS

JULIA A. GWYNNE is a Managing Director and Senior Research Scientist at the University of Chicago Consortium on School Research. She has conducted a number of studies examining the skills and academic behaviors students need to be ready for high school and college. She has also conducted research looking at high school graduation rates, charter high schools school closings, student mobility, and preschool attendance. Gwynne received her PhD in sociology from the University of Chicago.

SARAH E. CASHDOLLAR is a PhD student and Institute of Education Sciences (IES) pre-doctoral fellow in the Department of Comparative Human Development at the University of Chicago. She uses mixed methods to investigate the impacts of various ways schools prepare youth for attainment in college and careers. Her most current research uses a sociocultural developmental lens to examine student experiences in career and technical education programs. Prior to her studies at UChicago, Cashdollar worked as an elementary teacher in Dallas, Texas. She received her AB in anthropology from Dartmouth College.