Common Core State Standards for Mathematics and Assessments: (mis)Alignment

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Abstract

Common Core State Standards-Mathematics is written to increase the rigor of the curricula from kindergarten through twelfth grade. Additionally, these standards are designed to insure that the students build on and connect their mathematical knowledge from grade to grade. However, until assessment aligns with CCSS-M standards, the true achievement of students in the United States will likely be an unknown. This study examines the alignment between current assessments and the CCSS-M. This research suggests that current assessments will need to be revised to meet the CCSS-M.

Key terms: common core state standards (CCSS), assessment, alignment, achievement
Common Core State Standards for Mathematics and Assessments: (mis)Alignment

The perceived deficiencies of public prekindergarten-12 education in the United States have been troubling for many years. Any number of national and international student assessments show that students in the United States have mediocre to dismal performance in mathematics, science, and reading, e.g. Trends in International Mathematics and Science Studies, Programme for International Student Assessment, National Assessment of Educational Progress. Efforts to address low student achievement by offering students excellent educational opportunities are not new. As can be seen in the following list of legislation our government has made several attempts to mandate improved student performance. In 1965 Congress passed the Elementary and Secondary Education Act (P.L. 89-10) (ESEA), with multiple reauthorizations, which requires states to adopt educational curriculum standards based on the guidelines put forth by national educational organizations such as National Council of Teachers of Mathematics (NCTM), National Council for the Teachers of English (NCTE), etc. Education was again in the forefront in the 1980’s when the National Commission on Excellence in Education released its report entitled A Nation at Risk: An Imperative for Educational Reform (National Commission for the Excellence in Education, 1983) which emphasized, among many issues, the need for rigorous standards and increasing graduation rates for all high school students. More recently, the No Child Left Behind Act of 2001 (P. L. 107-110) was a reauthorization of ESEA which was intended to hold schools more accountable for student progress. As a result of No Child Left Behind (NCLB), states were required to assess all students through annual testing. However, educational rights remained firmly entrenched in state’s rights, until the release of the Common Core State Standards in June 2010 (Loveless, 2011).

The national standards movement was finally brought into reality when Council of Chief State School Officers (CCSSO) and the National Governors Association for Best Practices (NGA Center) joined forces to organize and develop national standards for mathematics and English/language arts (ELA). The purpose of the Common Core State Standards Initiative can be summed up as follows:

These Standards are not intended to be new names for old ways of doing business. They are a call to take the next step. . . . It is time to recognize that standards are not just promises to our children, but promises we intend to keep. (CCSS-M, 2010, p. 5)

The promise of new ways to do business (emphasis added by authors) leads to the creation of new methods for assessing student performance. However, a disconnect exists between the Common Core State Standards-Mathematics (CCSS-M) and assessments. New assessments are being written and existing assessments have not been aligned with the CCSS-M. Thus, the notion of transforming education in the United States through the use of national standards is solid; however, the results of using such standards will not be evident for at least seven years given the lack of appropriately aligned formalized assessments, e.g., ACT, SAT, etc. The purpose of this study is to analyze the alignment between the ACT test, which many students take as a college admission requirement, and the new CCSS-M that will guide student learning in mathematics.
Common Core State Standards-Mathematics Overview

The CCSSO and the NGA Center were strategic when selecting the writers of the CCSS-M. The designers of the CCSS-M were mathematicians, researchers, business leaders, and teachers. Further, drafts were released for public comment and direct input was sought from various professional organizations, such as NCTM and the Association of Mathematics Teacher Educators (AMTE). Writers were clear that they would not be bound by previous standards or opinions of others, but should carefully consider input from public drafts and revise the standards appropriately (CCSS, 2010).

Given that many people in the education profession believe that mathematics curricula across the United States are *a mile wide and an inch deep*, the CCSS-M authors wanted the new standards to reflect rigor and coherence. Further, they wanted the standards to be internationally benchmarked. Therefore, the overarching notion is that the CCSS-M will prepare students to be college and career ready. “College and Career Ready”, as originally defined by ACT and adopted for the CCSS, is

> The acquisition of the knowledge and skills a student needs to enroll and succeed in credit-bearing first-year courses at a postsecondary institution (such as a two- or four-year college, trade school, or technical school) without the need for remediation (ACT, 2010, pg. 3).

Nonetheless, various definitions and measures for career-ready exist. The Partnership for Assessment of Readiness for College and Careers, PARCC, (2012) has defined career-ready as a “Zone 3 job” (Edcounts, n.d.) meaning that a student that can enter the job market and obtain a position adequate to support a family, with benefits, and opportunity for promotion. The CCSS-M reflects a path from kindergarten through high school that allows students to scaffold their mathematical understanding to reach this college and career-ready definition.

The Standards

The CCSS-M, Standards for Mathematical Content, are divided by grade level guidelines. The grade level standards define progressions of knowledge and culminating competencies for each grade level. For instance, fractions are introduced in third grade with students mastering this concept by sixth grade. Fractions are not revisited again after the sixth grade, yet students are expected to use their knowledge of fractions on subsequent standards. While standards vary from grade to grade, they all contain some combination of domains such as: (a) Number and Operations.; (b) Measurement and Data; (c) Ratios and Proportional Relationships; (d) Expressions and Equations; (e) Functions; (g) Geometry; and (h) Statistics and Probability (CCSS, 2011).

In high school, CCSS-M provides two tracks for states to select. States may opt for traditionally named courses: Algebra I, Algebra II and Geometry. Or, the states can chose to teach integrated mathematics courses referred to as Math I, Math II and Math III. Whichever route is chosen, six conceptual categories exist for high school mathematics: (a) Number and
Quantity; (b) Algebra; (c) Functions; (d) Modeling; (e) Geometry; and (f) Statistics and Probability (CCSS, 2011). A casual study of the high school standards (Anderson & Franz, 2011) reveals that even though states may select the “traditional” courses, the course standards do not clearly align with the traditional courses or traditional assessments.

The Standards for Mathematical Practice and the Standards for Mathematical Content are designed to be used in tandem. The CCSS-M Standards for Mathematical Practice are mathematical habits, as described in previous research by NCTM (2000) and the National Research Council (2001), which all mathematicians must exhibit. In the 2000 NCTM Principles and Standards for School Mathematics, Process Standards were outlined as the processes good mathematicians use to do mathematics. These NCTM standards are consistent across all grade levels (NCTM, 2000). NCTM’s Process Standards are: (a) Problem Solving; (b) Reasoning and Proof; (c) Communication; (d) Connections; and (e) Representation (NCTM, 2000).

In 2001, the National Research Council released their report Adding It Up, which describes mathematical proficiency. The researchers describe mathematical proficiency as a braided rope whose individual braids are: (a) Conceptual Understanding; (b) Procedural Fluency (c) Strategic Competence; (d) Adaptive Reasoning; and (e) Productive Disposition.

The CCSS-M Standards for Mathematical Practice combine the research of both NCTM’s Process Standards (2000) and the National Research Council’s Adding It Up’s (2001) mathematical proficiencies and are written to “describe varieties of expertise that mathematics educators at all levels should seek to develop in their students” (CCSS, 2010, pg 6). The Standards of Mathematical Practice are: (a) make sense of problems and persevere in solving them, (b) reason abstractly and quantitatively, (c) construct viable arguments and critique the reasoning of others, (d) model with mathematics, (e) use appropriate tools strategically, (f) attend to precision, (g) look for and make use of structure, and (h) look for and express regularity in repeated reasoning (CCSS-M, 2010).

The new design of the mathematics standards requires new and extremely different assessments. Further, given that there is one set of standards, instead of each state creating its own; it no longer makes sense for each state to develop individual assessments. Therefore, a new national assessment needed to be designed.

Assessment Consortia for the CCSS

An important component of the CCSS-M is that assessments will become consistent across that states so that student performance is truly comparable. To date 46 states and the District of Columbia have chosen to adopt the CCSS for mathematics and English/language arts. As the CCSS have been developed, so are new methods for assessing student performance. Two assessment consortia, the Partnership for Assessment of Readiness for College and Careers (PARCC) and SMARTER Balanced Assessment Consortium (SBAC), were awarded federal grant dollars to develop assessments that align with the CCSS (Porter, McMaken, Hwang, & Yang, 2011). States may join one and/or both them. While the two consortia are developing their own assessments they are also working collaboratively to ensure that their tests are similar.
They are developing frameworks for comparing their assessments, so that as students move from a PARCC state to a SBAC state, their scores would be meaningful in both locations.

PARCC consists of 23 states, with Massachusetts serving as its Governing Chair (Sovde, 2012). This consortium will begin field testing its assessments in the 2012-2013 academic year in Indiana and Florida and will be “live” in 2014 (PARCC, 2012). SBAC consists of 25 states, with Vermont and Michigan as the co-chairs of the Executive Committee. SBAC will begin field testing in 2013 and plans to be operational by January 2015 (Educational Testing Service (ETS) b, 2011).

Institutes of Higher Learning

The CCSS Initiative is intended to be a comprehensive process that ultimately sends better prepared students to college (CCSS, 2010). Institutes of Higher Learning (IHLs) will need to respond both to the students entering their classes and to how they prepare future teachers. The most obvious changes will be needed in teacher education programs in both pedagogy and content. In theory, the type of student entering IHL’s should be incredibly different in the next few years as they will be, by definition, college and career ready. Institutes of Higher Learning have begun the process to acknowledge the potential changes from the implementation of CCSS-M. Two cross-institutional responses have been initiated by the Conference Board of Mathematical Sciences (CBMS) and the Association of Public and Land Grant Universities (APLU). The CBMS originally published a document entitled The Mathematical Education of Teachers in 2001. In October 2011, CBMS convened the Forum on Teaching Teachers in the Era of the Common Core to examine how to revise this document in light of the Common Core. This document will be used by many institutes to guide the mathematics content and mathematical pedagogy courses for pre-service teachers in elementary, middle and high schools. The APLU’s 2011 Initiative, Mathematics Teacher Education Partnership (MTE-P) examines how teacher education programs need to revamp their education of pre-service teachers and support and mentor in-service teachers. The MTE-P has drafted Guiding Principles designed to assist Colleges of Mathematics and Education as they revise their programs for preparing future teachers.

Predictive Studies

States who have adopted the CCSS are at various stages of implementation. Since PARCC and SBAC will not have their assessments in place until 2014, there is no data on student performance on the new standards. Therefore, many groups are working on alignment documents to predict how students will perform on the new assessments based on the curriculums or assessments that are currently being used. Authors were specifically interested in determining if and where ACT-assessed skills fell on the new CCSS continuum of mathematics. The purpose of this study was to map the CCSS-M to the American College Test (ACT) Readiness Standards in Mathematics.

Instrumentation

The ACT is defined as “a curriculum- and standards-based educational and career planning tool that assesses students’ academic readiness for college” (ACT, n.d.). One hundred
percent of colleges and universities accept the ACT as one measure in the admissions process for undergraduate college students and also use ACT scores to determine the readiness of students to enter credit-earning courses (ACT, 2010). The ACT provides benchmark scores through the use of subject-area tests which are mathematics, writing, English, and science. The ACT benchmarks predict that a score of 22 on the mathematics subtest indicates that a student has 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in college algebra (ACT, n.d.). The benchmarked college courses include English composition, college algebra, introductory social science courses, and biology.

In 2011, 49% of students in their senior in high school took the ACT. Of these students, only 25% of them scored at levels that met the benchmarking standards. As stated above, students need to score as 22 or higher to have a better than 50-50 chance to be successful in college algebra. The mathematics portion of the ACT has 60 questions. These questions are distributed across three major categories: (a) Pre-Algebra and Elementary Algebra, (b-) Intermediate Algebra and Coordinate Geometry and (c) Plane Geometry and Trigonometry.

Alignment Map

Researchers began the alignment process by studying the new CCSS-M documents, reviewed the development process described by CCSS-M writers and Learning Progressions drafts that are documents being written by the authors of CCSS-M to give teachers an understanding of how topics progress from grade to grade. Then researchers carefully studied the standards and example problems. Next, each ACT standard was compared to the CCSS-M to determine if or where a similar standard was present in the document. After making the determination, the CCSS-M standards were carefully reviewed and any samples or clarifying explanations were studied to confirm the placement.

The following tables show the alignment of standards or lack thereof between the CCSS-M and the ACT. There is one table for each of the eight ACT standards. Each table provides the breakdown of the scoring on the ACT, the readiness standard and then the mapped CCSS-M. If the CCSS-M has a number preceding the standards, then this concept occurs in the grade that is associated with the number. Otherwise, the concept is taught in high school mathematics courses.

The Basic Operations and Applications are mapped in Table 1. The left hand column gives the score range and the right hand column provides the cross-mapped CCSS-M. While most of the instruction occurs in high school for this category, making the connections to scores from 28-32 on the ACT relies on the rates, proportions or percentages that culminate in seventh grade mathematics courses.
Table 1

Basic Operations and Applications

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>Perform one-operation computation with whole numbers and decimals.</td>
<td>5 NBT 7</td>
</tr>
<tr>
<td></td>
<td>Solve problems in one or two steps using whole numbers.</td>
<td>4 OA 3</td>
</tr>
<tr>
<td></td>
<td>Perform common conversions (e.g., inches to feet or hours to minutes).</td>
<td>N-Q 1</td>
</tr>
<tr>
<td>16-19</td>
<td>Solve routine one-step arithmetic problems (using whole numbers, fractions, and decimals) such as single-step percent decimals) such as single-step percent.</td>
<td>A-SSE 1</td>
</tr>
<tr>
<td></td>
<td>Solve some routine two-step arithmetic problems.</td>
<td>N-Q 1, A-SSE 1</td>
</tr>
<tr>
<td>20-23</td>
<td>Solve routine two-step or three-step arithmetic problems involving concepts such as rate and proportion, tax added, percentage off, and computing with a given average.</td>
<td>N-Q 1, A-SSE 1</td>
</tr>
<tr>
<td>24-27</td>
<td>Solve multistep arithmetic problems that involve planning or converting units of measure (e.g., feet per second to miles per hour).</td>
<td>N-Q 1, N-Q 2, N-Q 3, A-SSE 1, G-MG 2</td>
</tr>
<tr>
<td>28-32</td>
<td>Solve word problems containing several rates, proportions, or percentages.</td>
<td>7 RP 3</td>
</tr>
<tr>
<td>33-36</td>
<td>Solve complex arithmetic problems involving percent of increase or decrease and problems requiring integration of several concepts from pre-algebra and/or pre-geometry (e.g., comparing percentages or averages, using several ratios, and finding ratios in geometry settings).</td>
<td>Not in CCSS</td>
</tr>
</tbody>
</table>

*Note: NBT=Number and Operation Base Ten; OA=Operations and Algebraic Thinking; N-Q=Quantities; A-SSE=Seeing Structure in Expressions; G-MG=Geometric Measurement and Dimension; RP=Ratios and Proportional Relationships.*

Table 2 displays the standards within Probability, Statistics and Data Analysis. The majority of this category is taught in high school. Note that some of this topic is not addressed in the CCSS-M.
### Table 2

**Probability, Statistics and Data Analysis**

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards Probability, Statistics and Data Analysis</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>Calculate the average of a list of positive whole numbers</td>
<td>6 SP 3</td>
</tr>
<tr>
<td></td>
<td>Perform a single computation using information from a table or chart</td>
<td>3 MD 3</td>
</tr>
<tr>
<td>16-19</td>
<td>Calculate the average of a list of numbers</td>
<td>6 SP 3, S-IC 4</td>
</tr>
<tr>
<td></td>
<td>Calculate the average, given the number of data values and the sum of the data values</td>
<td>6 SP 5</td>
</tr>
<tr>
<td></td>
<td>Read tables and graphs</td>
<td>N-Q1, S-ID 1</td>
</tr>
<tr>
<td></td>
<td>Perform computations on data from tables and graphs</td>
<td>5 MD 2</td>
</tr>
<tr>
<td></td>
<td>Use the relationship between the probability of an event and the probability of its complement</td>
<td>S-CP 1</td>
</tr>
<tr>
<td>20-23</td>
<td>Calculate the missing data value, given the average and all data values but one</td>
<td>7 EE 3</td>
</tr>
<tr>
<td></td>
<td>Translate from one representation of data to another (e.g. a bar graph to a circle graph)</td>
<td>S-CP 4, N-Q1, N-VM 6, S-ID 1, S-MD 1, 4</td>
</tr>
<tr>
<td></td>
<td>Determine the probability of a simple event</td>
<td>S-MD 3, 6, 7</td>
</tr>
<tr>
<td></td>
<td>Exhibit knowledge of simple counting techniques</td>
<td>S-CP 9</td>
</tr>
<tr>
<td>24-27</td>
<td>Calculate the average, given the frequency counts of all the data values</td>
<td>6 SP 5</td>
</tr>
<tr>
<td></td>
<td>Manipulate data from tables and graphs</td>
<td>F-IF 6, S-ID 32, 6, S-IC 4, S-MD 1, 4</td>
</tr>
<tr>
<td></td>
<td>Computer straightforward probabilities for common situations</td>
<td>S-IC 2, S-CP 1, 2, 7, S-MD 3, 6, 7</td>
</tr>
<tr>
<td></td>
<td>Use Venn diagrams in counting</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td>28-32</td>
<td>Calculate or use a weighted average</td>
<td>S-MD 2, 3, 4, 5</td>
</tr>
<tr>
<td></td>
<td>Interpret and use information from figures, tables, and graphs</td>
<td>N-Q 1, F-IF 9, F-LE 3, S-IC 1, 2, 4, 5, 6, S-ID 2, 3, 4, 6, 8 S-CP 9</td>
</tr>
<tr>
<td></td>
<td>Apply counting techniques</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td></td>
<td>Compute a probability when the event and/or sample space are not given or obvious</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td>33-36</td>
<td>Distinguish between mean, median, and mode for a list of numbers</td>
<td>S-ID 2</td>
</tr>
<tr>
<td></td>
<td>Analyze and draw conclusions based on information from figures, tables, and graphs</td>
<td>S-ID 9, S-IC 3, 6, S-MD 5, 7</td>
</tr>
<tr>
<td></td>
<td>Exhibit knowledge of conditional and joint probability</td>
<td>S-ID 5, S-CP 2, 3, 4, 5, 6, 8</td>
</tr>
</tbody>
</table>

*Note: SP=Statistics and Probability; MD=Measurement and Data; S-IC=Making Inferences and Justifying Conclusions; S-ID=Interpreting Categorical and Quantitative Data; S-CP=Conditional Probability and the Rules of Probability; EE-Evaluating Equations; N-VM=Vector and Matrix Quantities; N-Q=Quantities; S-MD=Using Probability to Make Decisions; F-IF=Interpreting Functions; F-FE=Linear, Quadratic, and Exponential Functions*
Table 3 displays the standard Numbers: Concepts and Properties. This standard contains concepts that are heavily emphasized in the middle grades or are not in the CCSS-M at all.

Table 3

Numbers: Concepts & Properties

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards Numbers: Concepts &amp; Properties</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>Recognize equivalent fractions and fractions in lowest terms</td>
<td>4NFI</td>
</tr>
<tr>
<td>16-19</td>
<td>Recognize one-digit factors of a number</td>
<td>1 NBT 1</td>
</tr>
<tr>
<td></td>
<td>Identify a digit’s place value</td>
<td>2 NBT 1</td>
</tr>
<tr>
<td>20-23</td>
<td>Exhibit knowledge of elementary number concepts including rounding, the ordering of decimals, patterns identification, absolute value, primes, and greatest common factor</td>
<td>F-IF 3</td>
</tr>
<tr>
<td>24-27</td>
<td>Find and use least common multiple</td>
<td>6 NS 4</td>
</tr>
<tr>
<td></td>
<td>Order fractions</td>
<td>4 NF 2</td>
</tr>
<tr>
<td></td>
<td>Work with numerical factors</td>
<td>7 EE 1</td>
</tr>
<tr>
<td></td>
<td>Work with scientific notation</td>
<td>8 EE 3, 4</td>
</tr>
<tr>
<td></td>
<td>Work with squares and square roots of numbers</td>
<td>8 EE 2, 8 NS 2</td>
</tr>
<tr>
<td></td>
<td>Work problems involving positive integer exponents</td>
<td>8 EE 1</td>
</tr>
<tr>
<td></td>
<td>Work with cubes and cube roots of numbers</td>
<td>8 EE 2</td>
</tr>
<tr>
<td></td>
<td>Determine when an expression is undefined</td>
<td>8 EE 8</td>
</tr>
<tr>
<td></td>
<td>Exhibit some knowledge of the complex numbers</td>
<td>N-CN 1, 7, A-REI 1, 4</td>
</tr>
<tr>
<td>28-32</td>
<td>Apply properties involving prime factorization</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td></td>
<td>Apply number properties involving even/odd numbers and factors/multiples</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td></td>
<td>Apply number properties involving positive/negative numbers</td>
<td>6 NS 6</td>
</tr>
<tr>
<td></td>
<td>Apply rules of exponents</td>
<td>N-RN 1, 2, A-SSE 3, F-IF 8</td>
</tr>
<tr>
<td></td>
<td>Multiply two complex numbers</td>
<td>N-CN 2, 8, 9</td>
</tr>
<tr>
<td>33-36</td>
<td>Draw conclusions based on number concepts, algebraic properties, and/or relationships between expressions and numbers</td>
<td>N-RN 3, A-APR 5</td>
</tr>
<tr>
<td></td>
<td>Exhibit knowledge of logarithms and geometric sequences</td>
<td>F-BF 2, 5, A-SSE 4, F-IF 3, 7, F-LE 1, 2, 4</td>
</tr>
<tr>
<td></td>
<td>Apply properties of complex numbers</td>
<td>N-CN 3, 4, 5, 6, 8, 9</td>
</tr>
</tbody>
</table>

Note: NF=Number and Operations-Fractions; NBT=Number and Operations Base Ten; F-IF=Interpreting Functions; NS=The Number System; EE=Evaluating Expressions; N-CN=The Complex Number System; A-REI=Reasoning with Equations and Inequalities; N-RN=The Real Number System; A-SSE=Seeing Structure in Expressions; A-APR=Arithmetic with Polynomials and Rational Expressions; F-BF=Building Functions; F-LE=Linear, Quadratic and Exponential Functions

Expressions, Equations and Inequalities are listed in Table 4. Most of the material contained in this category is taught in high school. However, the standard Expressions and Equations first appears in 8th grade.
### Table 4

**Expressions, Equations & Inequalities.**

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>Exhibit knowledge of basic expressions (e.g. identify an expression for a total as ( b+g ))</td>
<td>5 OA 2</td>
</tr>
<tr>
<td></td>
<td>Solve equations in the form ( x+a=b ), where ( a ) and ( b ) are whole numbers or decimals</td>
<td>8 EE 7</td>
</tr>
<tr>
<td>16-19</td>
<td>Substitute whole numbers for unknown quantities to evaluate expressions</td>
<td>6 EE 2</td>
</tr>
<tr>
<td></td>
<td>Solve one-step equations having integer or decimal answers</td>
<td>A-SSE 1</td>
</tr>
<tr>
<td></td>
<td>Combine like term (e.g. ( 2x+5x ))</td>
<td>A-SSE 1, 2</td>
</tr>
<tr>
<td>20-23</td>
<td>Evaluate algebraic expressions by substituting integers for unknown quantities</td>
<td>A-CED 1, 2, 3, F-IF 9</td>
</tr>
<tr>
<td></td>
<td>Add and subtract simple algebraic expressions</td>
<td>A-SSE 2</td>
</tr>
<tr>
<td></td>
<td>Solve routine first-degree equations</td>
<td>A-SSE 1, A-CED 1, A-REI 3</td>
</tr>
<tr>
<td></td>
<td>Perform straightforward word-to-symbol translations</td>
<td>A-SSE 1, A-CED 1</td>
</tr>
<tr>
<td></td>
<td>Multiply two binomials</td>
<td>A-SSE 2</td>
</tr>
<tr>
<td>24-27</td>
<td>Solve real-world problems using first-degree equations</td>
<td>N-Q 1, A-SSE 1, A-CED 1</td>
</tr>
<tr>
<td></td>
<td>Write expressions, equations, or inequalities with a single variable for common pre-algebra settings (e.g. rate and distance problems and problems that can be solved by using proportions)</td>
<td>N-Q 1, 2, A-SSE 1, A-CED 1, F-IF 5, F-BF 1, 2, F-LE 1, 2, 5</td>
</tr>
<tr>
<td></td>
<td>Identify solutions to simple quadratic equations</td>
<td>A-CED 1, A-REI 4, 12</td>
</tr>
<tr>
<td></td>
<td>Add, subtract, multiply polynomials</td>
<td>A-SSE 2, A-APR 1</td>
</tr>
<tr>
<td></td>
<td>Factor simple quadratics (e.g. the difference of squares and perfect square trinomials)</td>
<td>A-SSE 2, 3, A-CED 1, A-REI 4, F-IF 8</td>
</tr>
<tr>
<td></td>
<td>Solve first-degree inequalities that do not require reversing the inequality sign</td>
<td>A-CED 1, 3, A-REI 3</td>
</tr>
<tr>
<td>28-32</td>
<td>Manipulate expressions and equations</td>
<td>N-CN 8, N-VM 3, 4, 5, 7, 8, 9, 10, 11, A-SSE 1, 2, 3, 4, A-APR 2, 4, 6, 7, A-REI 1, 3, 4, 8, 9, 12, F-IF 2, 8, 9, F-BF 2, G-GPE 1</td>
</tr>
<tr>
<td></td>
<td>Write expressions, equations and inequalities for common algebra settings</td>
<td>N-Q 2, A-SSE 1, A-CED 1, 2, 3, A-REI 2, F-IF 3, 5, F-BF 1, 2, F-LE 1, 2, 5</td>
</tr>
<tr>
<td></td>
<td>Solve linear inequalities that require reversing the inequality sign</td>
<td>A-CED 1, 3, A-REI 3</td>
</tr>
<tr>
<td></td>
<td>Solve absolute value equations</td>
<td>6 NS 7</td>
</tr>
<tr>
<td></td>
<td>Solve quadratic equations</td>
<td>N-CN 7, 8, 9, A-SSE 3, A-CED 1, A-REI 7</td>
</tr>
<tr>
<td></td>
<td>Find solutions to systems of linear equations</td>
<td>A-REI 5, 6</td>
</tr>
</tbody>
</table>
Table 5 shows Graphic Representations. It is interesting to note that the first component of Graphic Representations is first presented in second grade. Thus, students must recall content from elementary mathematics in order to be successful on the ACT under the new CCSS-M.

Table 5

<table>
<thead>
<tr>
<th>Graphic Representations</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>To score on ACT</td>
<td>ACT Math College Readiness Standards</td>
<td>Math Common Core</td>
</tr>
<tr>
<td></td>
<td>Graphical Representations</td>
<td></td>
</tr>
<tr>
<td>13-15</td>
<td>Identify the location of a point with a positive coordinate on the number line</td>
<td>2 MD 6</td>
</tr>
<tr>
<td>16-19</td>
<td>Locate points on the number line and in the first quadrant</td>
<td>5 G 1</td>
</tr>
<tr>
<td>20-23</td>
<td>Locate points in the coordinate plane</td>
<td>S-ID 6, F-IF 7, A-CED 1, 2, A-REI 10</td>
</tr>
<tr>
<td></td>
<td>Comprehend the concept of length on the number line</td>
<td>2 MD 6</td>
</tr>
<tr>
<td></td>
<td>Exhibit knowledge of slope</td>
<td>F-IF 6, S-ID 7, 8 EE 5</td>
</tr>
<tr>
<td>24-27</td>
<td>Identify the graph of a linear inequality on the number line</td>
<td>A-REI 10</td>
</tr>
<tr>
<td></td>
<td>Determine the slope of a line from points or equations</td>
<td>S-ID 6, 7, G-GPE 4, 5, F-IF 6, F-LE 1, 2</td>
</tr>
<tr>
<td></td>
<td>Match linear graphs with their equations</td>
<td>G-GPE 4, S-ID 6, A-CED 1, 2, 3, F-IF 7, F-LE 1, 2</td>
</tr>
<tr>
<td></td>
<td>Find the midpoint of a line segment</td>
<td>N-CN 6, G-GPE 6</td>
</tr>
<tr>
<td>28-32</td>
<td>Interpret and use information from graphs in the coordinate plane</td>
<td>G-CO 2, 5, 6, G-SRT 1, F-BF 3, 4, F-LE 1, 2, 3, A-REI 10, 11, F-IF 1, 4, 5, 6, 7, 8, 9, G-GPE 4, S-ID 6, N-Q 1, N-VM 1, 2, 3, 4, 5, A-APR 3, A-CED 1, 2, 3</td>
</tr>
<tr>
<td></td>
<td>Match number line graphs with solutions sets linear inequalities</td>
<td>A-CED 1</td>
</tr>
<tr>
<td></td>
<td>Use the distance formula</td>
<td>G-GPE 4, 6, 7</td>
</tr>
<tr>
<td></td>
<td>Use properties of parallel and perpendicular lines to determine an equation of a line or coordinates of a point</td>
<td>G-GPE 4, 5</td>
</tr>
<tr>
<td></td>
<td>Recognize special characteristics of parabolas and circles (e.g. the vertex of a parabola and the center or radius of a circle)</td>
<td>G-GPE 2, F-IF 7, F-BF 3</td>
</tr>
<tr>
<td>33-36</td>
<td>Match number line graphs with solution sets of simple quadratic inequalities. Identify characteristics of graphs based on a set of conditions or on a general equation such as ( y=ax^2+c ). Solve problems integrating multiple algebraic and/or geometric concepts. Analyze and draw conclusions based on information from graphs in the coordinate plane.</td>
<td>A-CED 1, G-PGE 2, 3, A-APR 3, F-IF 7, F-BF 3, 4, G-CO 4, N-VM 11, 12, G-CO 4. Not in CCSS.</td>
</tr>
</tbody>
</table>

**Note:** MD=Measurement and Data; G=Geometry; S-ID=Interpreting Categorical and Quantitative Data; F-IF=Interpreting Functions; A-CED=Creating Equations; A-REI=Reasoning with Equations and Inequalities; F-LE=Linear, Quadratic and Exponential Models; EE=Evaluating Equations; G-PGE=Expressing Geometric Properties with Equations; N-CN=The Complex Number System; G-CO=Congruence; G-SRT=Similarity, Right Triangles, and Trigonometry; N-Q=Quantities; N-VM=Vector and Matrix Quantities; A-APR=Arithmetic with Polynomials and Rational Expressions.

**Properties of Plane Figures (Table 6) are taught in high school. However, they are spread across many CCSS-M domains and span several grade levels.**

**Table 6**

**Properties of Plane Figures**

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>N/A</td>
<td>8G 1, G-CO 1</td>
</tr>
<tr>
<td>16-19</td>
<td>Exhibit some knowledge of the angles associated with parallel lines</td>
<td>G-CO 1,9,10,11,12, G-SRT 3,4, G-MG 3</td>
</tr>
<tr>
<td>20-23</td>
<td>Find the measure of an angle using properties of parallel lines</td>
<td>G-CO 1,9,10,11,12, G-SRT 3,4, G-MG 3</td>
</tr>
<tr>
<td></td>
<td>Exhibit knowledge of basic angle properties and special sums of angle measures</td>
<td>8G 5, G-CO 1,9,10,11,12, G-MG 3</td>
</tr>
<tr>
<td>24-27</td>
<td>Use several angle properties to find an unknown angle measure</td>
<td>G-CO 9,10,11,12, G-SRT 3,4, G-MG 3</td>
</tr>
<tr>
<td></td>
<td>Recognize Pythagorean triples</td>
<td>N-VM 3, G-CO 12, 8G 6, G-MG 3</td>
</tr>
<tr>
<td></td>
<td>Use properties of isosceles triangles</td>
<td>G-CO 10,11,12</td>
</tr>
<tr>
<td>28-32</td>
<td>Apply properties of 30-60-90, 45-45-90, similar, and congruent triangles</td>
<td>G-CO 2,3,6,7,8,10,11,12, N-VM 3, G-MG 3, G-SRT 2,3,4,5,6, G-C 1,5, G-PGE 6</td>
</tr>
<tr>
<td></td>
<td>Use the Pythagorean Theorem</td>
<td>G-MG 3, G-CO 12, G-SRT 4, G-GPE 1, 8G 7</td>
</tr>
<tr>
<td>33-36</td>
<td>Draw conclusions based on a set of conditions</td>
<td>G-CO 4,7,8,9,10,11, G-SRT 10,11, G-C 1,5, G-MG 3</td>
</tr>
</tbody>
</table>

**Note:** G=Geometry; G-CO=Congruence; G-SRT=Similarity, Right Triangles, and Trigonometry; G-MG=Modeling with Geometry; N-VM=Vector and Matrix Quantities; G-C=Circles; G-PGE=Expressing Geometric Properties with Equations; G-MGD=Geometric Measurement and Dimensions.

Measurement (Table 7) has concepts that are covered as early as third grade. Students are required to be fluent in these topics long before high school so that they can easily connect the measurement to more abstract concepts.
Table 7
Measurement

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>Estimate or calculate the length of a line segment based on other lengths given on a geometric figure</td>
<td>4 G 1, 7 G 1</td>
</tr>
<tr>
<td>16-19</td>
<td>Compute the perimeter of polygons when all side lengths are given</td>
<td>3 MD 8</td>
</tr>
<tr>
<td></td>
<td>Compute the area of rectangles when whole number dimensions are given</td>
<td>4 MD 3</td>
</tr>
<tr>
<td>20-23</td>
<td>Compute the area and perimeter of triangles and rectangles in simple problems</td>
<td>G-MG 1, 3</td>
</tr>
<tr>
<td></td>
<td>Use geometric formulas when all necessary information is given</td>
<td>G-GMD 3, G-MG 1, 2, 3</td>
</tr>
<tr>
<td>24-27</td>
<td>Compute the area of triangles and rectangles when one or more additional simple steps are required</td>
<td>G-MG 1, 3</td>
</tr>
<tr>
<td></td>
<td>Compute the area and circumference of circles after identifying necessary information</td>
<td>G-GMD 1, G-MG 1, 3</td>
</tr>
<tr>
<td></td>
<td>Compute the perimeter of simple composite geometric figures with unknown side lengths</td>
<td>G-GMD 1, G-MG 1, 3</td>
</tr>
<tr>
<td>28-32</td>
<td>Use relationships involving area, perimeter, and volume of geometric figures to compute another measure</td>
<td>G-GMD 1, 2, G-GMD 3</td>
</tr>
<tr>
<td>33-36</td>
<td>Use scale factors to determine the magnitude of a size change</td>
<td>Not in CCSS</td>
</tr>
<tr>
<td></td>
<td>Compute the area of composite geometric figures when planning or visualization is required</td>
<td>G-GMD 2</td>
</tr>
</tbody>
</table>

Note: G=Geometry; MD=Measurement and Data; G-MG=Modeling with Geometry; G-GMD= Geometric Measurement and Dimension

Functions as a standard do not occur until high school in CCSS-M. Previous to high school students are studying algebraic thinking and equations to build the knowledge necessary to understand functions. Table 8 shows the multiple standards that contain Functions.

Table 8
Functions

<table>
<thead>
<tr>
<th>To score on ACT</th>
<th>ACT Math College Readiness Standards</th>
<th>Math Common Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>16-19</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>20-23</td>
<td>Evaluate quadratic functions, expressed in function notation, at integer values</td>
<td>F-IF 1, 2, 6, F-BF 2</td>
</tr>
<tr>
<td>24-27</td>
<td>Evaluate polynomial functions, expressed in function notation, at integer values</td>
<td>F-IF 2, 3, 6, F-BF 2</td>
</tr>
<tr>
<td></td>
<td>Express the sine, cosine, and tangent of an angle in a right triangle as a ratio of given side lengths</td>
<td>N-VM 3, G-SRT 6, F-TF 3, F-IF 2</td>
</tr>
</tbody>
</table>
Evaluate composite functions at integer values

Apply basic trigonometric ratios to solve right-triangle problems

Write an expression for the composite of two simple functions

Use trigonometric concepts and basic identities to solve problems

Exhibit knowledge of unit circle trigonometry

Match graphs of basic trigonometric functions with their equations

Note: F-IF=Interpreting Functions; F-BF=Building Functions; N-VM=Vector and Matrix Quantities; G-SRT=Similarity, Right Triangles and Trigonometry; F-TF=Trigonometric Functions; G=Circles

Table 9 lists the ACT college readiness skills that do not appear on the CCSS-M. Though not on the CCSS-M, the ACT will continue to assess students’ knowledge of these mathematical concepts.

Table 9
Skills not in CCSS

Solve complex arithmetic problems involving percent of increase or decrease and problems requiring integration of several concepts from pre-algebra and/or pre-geometry (e.g., comparing percentages or averages, using several ratios, and finding ratios in geometry settings).

Use Venn diagrams in counting

Compute a probability when the event and/or sample space are not given or obvious

Apply properties involving prime factorization

Apply number properties involving even/odd numbers and factors/multiples

Analyze and draw conclusions based on information from graphs in the coordinate plane

Use scale factors to determine the magnitude of a size change

Findings

While the majority of ACT college readiness skills are taught in the CCSS-M high school standards, there are some notable exceptions. There is at least one and as many as nine concepts that are taught in middle grades mathematics in every ACT broad category except functions. Additionally, there are several standards that do not appear to be located in the CCSS-M. These may be concepts that are implicit in the CCSS-M, but are not clearly delineated. As such, these concepts may or may not be taught formally in schools. Most of these “missing” standards are appropriate for and can be found in middle school mathematics courses. Finally, on the ACT, students’ scores increase as they are able to show mastery of progressively more complicated concepts. Many of the concepts may be culminating standards in high school, but are introduced
in middle and even elementary classrooms, effectively making “mastery” a long and possibly challenging process.

For many of the ACT Standards there are multiple CCSS-M standards that address the content and concepts. This may indicate that the CCSS-M standards are incredibly dense. This means that teachers will need to be aware of the connections both among the standards at a given level but with the vertical alignment or learning progression of concepts. Therefore, these findings may support the claims that the new CCSS-M significantly changes k-12 mathematics, meaning that how we assess mathematics must also change.

**Conclusions and Implications**

ACT (2010) identified three areas in which mathematics instruction needs to improve under CCSS—Number and Quantity, support for at-risk learners, and conceptual understanding of mathematical process and practices (Anderson & Franz, 2011). This study indicates that portions of the ACT are dependent on learning that begins in the middle grades, and sometimes in elementary school. This study also reveals that perfect alignment between the new CCSS-M and the ACT does not exist. In fact, there are concepts within all of the broad ACT standards that are not explicitly taught in the CCSS-M yet students are expected to have mastered the content.

Implementation of CCSS is only beginning so available research is limited. It will likely be several years before assessment data can be used to evaluate achievement gains for students. Findings of this study indicate that current assessment instruments, such as the ACT, need to be realigned with the new CCSS-M so that student performance is accurately measured and reported. Currently, and until the new assessments from PARRC and SBAC for the CCSS-M are used regularly, students matriculating through public schools in Common Core states, will be assessed with a measure, the ACT, that is no longer an accurate measure of students’ knowledge. Likewise, colleges and universities will need to reassess their admission standards and course placement practices.

Based on the alignment map, this data supports the claim that teachers will need to enter the classroom with new or, at least, different types of knowledge and understandings about mathematics. This data also suggests that middle school mathematics teachers play a vital role in preparing students for the ACT and future collegiate success. This conclusion supports the initial work of groups like the CBMS and MTE-P, who are calling for major revisions to the mathematical content courses taken by pre-service middle school teachers. No longer will procedural knowledge of mathematical principles be enough—preservice and practicing teachers will need to have mastery of all content they are expected to teach so that they are able to teach conceptually. Teaching conceptually will allow students to master, over a series of grade levels, mathematical concepts needed in high school and beyond. As evident in this analysis, the move to CCSS-M standards is a positive one—it ought to increase the rigor of the kindergarten-twelfth grade curricula as well as capitalize on learning experiences in previous grades making public schools mathematics a more cohesive system. However, until assessment measures align with CCSS-M standards, the true achievement of students in the United States will likely be an
unknown. And, aptitude for and persistence in colleges and universities courses will be difficult to determine based on current assessment measures.

References


