

INTRODUCTION TO THE HIGH SCHOOL STANDARDS ANALYSIS

The Standards for Mathematical Practice are common to both high school and grades K–8, but the Standards for Mathematical Content are organized differently in high school than in grades K–8. In grades K–8, the content standards are organized in a yearly sequence. In high school, the content standards are organized not by year but rather by conceptual category (Functions, Algebra, etc.).

The Model Content Frameworks provide an analysis of the high school standards using terms and conventions similar to those used for the grades 3–8 standards analyses. With the 2012 version of the Model Content Frameworks, this is done by providing end-of-course assessment boundaries for six courses: Algebra I, Geometry, Algebra II, and Mathematics I, Mathematics II, and Mathematics III.¹ In each case, relative cluster emphases (Major, Additional, and Supporting) are provided as are denotations regarding which standards, or parts of standards, are eligible for assessment for each test.²

There are two sections to the high school standards analysis:

1. **Course-specific analysis** of the high school standards: analysis of emphasis and boundaries presented with a view toward two sequences of end-of-course assessments.
2. **General analysis** of the high school standards: analysis that is independent of any particular organization of the standards into courses.

Please note: The reader is advised to have a copy of *Common Core State Standards for Mathematics* available for use in conjunction with this document. The Model Content Frameworks paraphrase the standards and in some cases refer to standards by number or code only; readers will need to refer to the standards document for exact language.

¹ Two different pathways are provided, as the PARCC Assessment System calls for the creation of assessments for each.

² Note that the courses outlined in the Model Content Frameworks were informed by, but are not identical to, previous drafts of this document and Appendix A of the Common Core State Standards.

High School Standards Analysis: Course-Specific Analyses Introduction

End-of-Course High School Summaries and Standards Analysis

This section of the document is intended to summarize the high school standards to be assessed on each PARCC end-of-course assessment. A brief analysis of the standards in each course is also provided. Two pathways are included, AI-G-AII and MI-MII-MIII.

For each high school pathway, the following information is provided:

- **Individual end-of-course overviews.** Each overview shows which standards are assessed on a given end-of-course assessment as well as relative cluster emphases.
- **For each course:**
 - Examples of key advances from previous grades or courses.
 - Discussion of Mathematical Practices in relation to course content.
 - Fluency recommendations
- **Pathway summary table.** The pathway summary table shows three end-of-course assessments' standards at a glance.
- **Assessment limits table for standards assessed on more than one end-of-course test.** Some high school standards are appropriate for more than one end-of-course assessment. The assessment limits table provides information on how a standard is assessed differently on each end-of-course assessment.

Individual end-of-course overviews

Each individual end-of-course overview lists the domains, clusters, and standards assessed on a particular end-of-course test. In listing domains, domain codes from the *Common Core State Standards for Mathematics* (CCSSM) have been used. For example, the CCSSM domain "Seeing Structure in Expressions" carries the code A-SSE. The first letter of the code represents the CCSSM category, Algebra in this case, while the second part of the code represents the domain "Seeing Structure in Expressions".

Clusters are listed within domains. Following each cluster is a numerical list of standards enclosed in parentheses. If a number is underlined, it will be assessed on more than one end-of-course assessment.

Consistent with the *PARCC Model Content Frameworks* for grades 3-8 and the PARCC assessment claims, each course cluster has been designated as major, additional, or supporting. As noted in the *PARCC Model Content Frameworks*, "Some clusters require greater emphasis than the others based on the depth of the ideas, the time that they take to master, and/or their importance to future mathematics or the demands of college and career readiness. In addition, an intense focus on the most critical material ... allows depth in learning, which is carried out through the Standards for Mathematical Practice. Without such focus, attention to the practices would be difficult and unrealistic, as would best practices

like formative assessment.” Therefore, to make relative emphases in the standards more transparent and useful, clusters are designated as Major, Additional and Supporting for the course in question. Note in particular that some clusters that are not major emphases in themselves are designed to *support* and strengthen areas of major emphasis, while other clusters that may not connect tightly or explicitly to the major work of the grade would fairly be called *additional*. Across the two pathways, if a cluster is designated as Major at any point in one pathway, it is also designated as Major at some point in the other pathway.

To say that some things have greater emphasis is not to say that anything in the standards can safely be neglected in instruction. Neglecting material will leave gaps in student skill and understanding and may leave students unprepared for the challenges of a later course. All non-(+) standards figure in a mathematical education leading to college and career readiness, and will therefore be eligible for inclusion on the PARCC assessment. The assessments will mirror the message that is communicated here: Major Clusters will be a majority of the assessment, Supporting Clusters will be assessed through their success at supporting the Major Clusters and Additional Clusters will be assessed as well. The assessments will strongly focus where the standards strongly focus.

Examples of Key Advances from Previous Grades or Courses

- This category highlights some of the major steps in the progression of increasing knowledge and skill from year to year. Note that each key advance in mathematical content also corresponds to a widening scope of problems that students can solve. Examples of key advances are highlighted to stress the need for curricula to treat topics in ways that take into account where students have been in previous grades or courses and where they will be going in subsequent courses.

Discussion of Mathematical Practices in Relation to Course Content

- This category highlights some of the mathematical practices and describes how they play a role in each course. These examples are provided to stress the need to connect content and practices, as required by the standards.
- In addition to the examples provided in each course, the following are some general comments about connecting content and practices:
 - Connecting content and practices happens in the context of **working on problems**. The very first Standard for Mathematical Practice is to make sense of problems and persevere in solving them (MP.1).
 - The Standards for Mathematical Practice interact and overlap with each other. **They are not a checklist.**
 - Modeling with mathematics is a theme in all high school courses. Modeling problems in high school center on problems arising in everyday life, society and the workplace. Such problems may draw upon mathematical content knowledge and skills articulated in the standards prior to or during the current course. (For more information on modeling in high school, see pages 72 and 73 of the *Common Core State Standards in Mathematics*.)

Fluency Recommendations

- The high school standards do not set explicit expectations for fluency nor will the PARCC assessments address fluency, but fluency is important in high school mathematics. For example, fluency in algebra can help students get past the need to manage computational details so that they can observe structure and patterns in problems. Such fluency can also allow for smooth progress beyond the college and career readiness threshold toward readiness for further study/careers in science, technology, engineering and mathematics (STEM) fields. Therefore, this section makes recommendations about fluencies that can serve students well as they learn and apply mathematics. These fluencies are highlighted to stress the need for curricula to provide sufficient supports and opportunities for practice to help students gain fluency. Fluency is not meant to come at the expense of understanding; it is an outcome of a progression of learning and thoughtful practice. Curricula must provide the conceptual building blocks that develop in tandem with skill along the way to fluency.

Please Note

- The words *examples* and *opportunities* in the above categories emphasize that the analysis provided in each category is not exhaustive. For example, there are many opportunities to connect mathematical content and practices in every course, there are many opportunities for in-depth focus in every grade, and so on. A comprehensive description of these features of the standards would be hundreds of pages long. ***The analyses given here should be thought of as starting points.***
- Always refer back to the *Common Core State Standards for Mathematics* for exact language about student expectations.

Pathway summary tables (Table 1 and Table 3)

Each pathway summary table shows three end-of-course assessments' standards at a glance. For each non-(+) high school standard, the end-of-course assessment(s) assessing the standard are shown by a dot (•) symbol. Shading in the pathway summary table indicates high school standards that are appropriate for more than one end-of-course assessment.

The information in each pathway summary table is consistent with the pathway's preceding end-of-course overviews. The pathway summary table also provides additional detail by showing which lettered sub-parts of standards are assessed on which end-of-course assessment(s).

Assessment limits tables for standards assessed on more than one end-of-course test (Table 2 and Table 4)

When a high school standard is appropriate for more than one end-of-course test in a given pathway, the need arises to specify just how the assessment of the standard will differ for students in each successive course. This information is provided in the assessment limits tables.

In setting such assessment limits, one must balance the need for focus and specificity against the need for mathematical generality and coherence. With too many limits, enduring understandings might

become artificially obscured. And yet at the same time, the road to enduring understanding needs clear signposts. With too few limits, teachers and students don't know what to focus on, and task developers do not have sufficient guidance.

In general, the approach to striking this balance has been to set stricter limits on standards relating to procedural skill, and to set less strict limits on standards relating to conceptual understanding and exploration. And the number of standards assessed on more than one end-of-course assessment has been kept as small as seems possible, so as to keep the number of standards in each course from becoming too large.

A Note About (+) Standards. This document includes only the Standards for Mathematical Practice as well as the non-(+) Standards for Mathematical Content. However, the final version of the *PARCC Model Content Frameworks* might include (+) standards, in order to show how they may be coherently included in high school. Course-specific analysis is then provided in the following categories:

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PARCC MODEL CONTENT FRAMEWORK FOR MATHEMATICS FOR ALGEBRA I

Algebra I Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 1 and 2. Course emphases are indicated by: ■ Major Content; ■ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

The Real Number System (N-RN)

- Use properties of rational and irrational numbers (3)

Quantities* (N-Q)

- Reason quantitatively and use units to solve problems (1, 2, 3)

Seeing Structure in Expressions (A-SSE)

- Interpret the structure of expressions (1, 2)
- Write expressions in equivalent forms to solve problems (3)

Arithmetic with Polynomials and Rational Expressions (A-APR)

- Perform arithmetic operations on polynomials (1)
- Understand the relationship between zeros and factors of polynomials (3)

Creating Equations* (A-CED)

- Create equations that describe numbers or relationships (1, 2, 3, 4)

Reasoning with Equations and Inequalities (A-REI)

- Understand solving equations as a process of reasoning and explain the reasoning (1)
- Solve equations and inequalities in one variable (3, 4)
- Solve systems of equations (5, 6)
- Represent and solve equations and inequalities graphically (10, 11, 12)

Mathematical Practices

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

Interpreting Functions (F-IF)

- Understand the concept of a function and use function notation (1, 2, 3)
- Interpret functions that arise in applications in terms of the context (4, 5, 6)
- Analyze functions using different representations (7, 8, 9)

Building Functions (F-BF)

- Build a function that models a relationship between two quantities (1)
- Build new functions from existing functions (3)

Linear, Quadratic, and Exponential Models* (F-LE)

- Construct and compare linear, quadratic, and exponential models and solve problems (1, 2, 3)
- Interpret expressions for functions in terms of the situation they model (5)

Interpreting categorical and quantitative data (S-ID)

- Summarize, represent, and interpret data on a single count or measurement variable (1, 2, 3, 4)
- Summarize, represent, and interpret data on two categorical and quantitative variables (5, 6)
- Interpret linear models (7, 8, 9)

Examples of Key Advances from Grades K–8

- Having already extended arithmetic from whole numbers to fractions (grades 4–6) and from fractions to rational numbers (grade 7), students in grade 8 encountered particular irrational numbers such as $\sqrt{5}$ or π . In Algebra I, students will begin to understand the real number *system*. For more on the extension of number systems, see page 58 of the standards.
- Students in middle grades worked with measurement units, including units obtained by multiplying and dividing quantities. In Algebra I, students apply these skills in a more sophisticated fashion to solve problems in which reasoning about units adds insight (N-Q).
- Themes beginning in middle school algebra continue and deepen during high school. As early as grades 6 and 7, students began to use the properties of operations to generate equivalent expressions (6.EE.3, 7.EE.1). By grade 7, they began to recognize that rewriting expressions in different forms could be useful in problem solving (7.EE.2). In Algebra I, these aspects of algebra carry forward as students continue to use properties of operations to rewrite expressions, gaining fluency and engaging in what has been called “mindful manipulation.”³
- Students in grade 8 extended their prior understanding of proportional relationships to begin working with functions, with an emphasis on linear functions. In Algebra I, students will master linear and quadratic functions. Students encounter other kinds of functions to ensure that general principles are perceived in generality, as well as to enrich the range of quantitative relationships considered in problems.
- Students in grade 8 connected their knowledge about proportional relationships, lines and linear equations (8.EE.5, 6). In Algebra I, students solidify their understanding of the analytic geometry of lines. They understand that in the Cartesian coordinate plane:
 - The graph of any linear equation in two variables is a line.
 - Any line is the graph of a linear equation in two variables.
- As students acquire mathematical tools from their study of algebra and functions, they apply these tools in statistical contexts (e.g., S-ID.6). In a modeling context, they might informally fit a quadratic function to a set of data, graphing the data and the model function on the same coordinate axes. They also draw on skills they first learned in middle school to apply basic statistics and simple probability in a modeling context. For example, they might estimate a measure of center or variation and use it as an input for a rough calculation.
- Algebra I techniques open a huge variety of word problems that can be solved that were previously inaccessible or very complex in grades K–8. This expands problem solving from grades K–8 dramatically.

Discussion of Mathematical Practices in Relation to Course Content

Two overarching practices relevant to Algebra I are:

- **Make sense of problems and persevere in solving them (MP.1).**

³ See, for example, “Mindful Manipulation,” in *Focus in High School Mathematics: Reasoning and Sense Making* (National Council of Teachers of Mathematics, 2009).

- **Model with mathematics** (MP.4).

Indeed, other mathematical practices in Algebra I might be seen as contributing specific elements of these two. The intent of the following set is not to decompose the above mathematical practices into component parts but rather to show how the mathematical practices work together.

- **Reason abstractly and quantitatively** (MP.2). This practice standard refers to one of the hallmarks of algebraic reasoning, the process of decontextualization and contextualization. Much of elementary algebra involves creating abstract algebraic models of problems (A-CED, F-BF) and then transforming the models via algebraic calculations (A-SSE, A-APR, F-IF) to reveal properties of the problems.
- **Use appropriate tools strategically** (MP.5). Spreadsheets, a function modeling language, graphing tools and many other technologies can be used strategically to gain understanding of the ideas expressed by individual content standards and to model with mathematics.
- **Attend to precision** (MP.6). In algebra, the habit of using precise language is not only a mechanism for effective communication but also a tool for understanding and solving problems. Describing an idea precisely (A-CED, A-REI) helps students understand the idea in new ways.
- **Look for and make use of structure** (MP.7). For example, writing $49x^2 + 35x + 6$ as $(7x)^2 + 5(7x) + 6$, a practice many teachers refer to as “chunking,” highlights the structural similarity between this expression and $z^2 + 5z + 6$, leading to a factorization of the original: $(7x + 3)(7x + 2)$ (A-SSE, A-APR).
- **Look for and express regularity in repeated reasoning** (MP.8). Creating equations or functions to model situations is harder for many students than working with the resulting expressions. An effective way to help students develop the skill of describing general relationships is to work through several specific examples and then express what they are doing with algebraic symbolism (A-CED). For example, when comparing two different text messaging plans, many students who can compute the cost for a given number of minutes have a hard time writing general formulas that express the cost of each plan for *any* number of minutes. Constructing these formulas can be facilitated by methodically calculating the cost for several different input values and then expressing the steps in the calculation, first in words and then in algebraic symbols. Once such expressions are obtained, students can find the break-even point for the two plans, graph the total cost against the number of messages sent and make a complete analysis of the two plans.

Fluency Recommendations

- A/G** Algebra I students become fluent in solving characteristic problems involving the analytic geometry of lines, such as writing down the equation of a line given a point and a slope. Such fluency can support them in solving less routine mathematical problems involving linearity, as well as in modeling linear phenomena (including modeling using systems of linear inequalities in two variables).
- A-APR.1** Fluency in adding, subtracting and multiplying polynomials supports students throughout their work in algebra, as well as in their symbolic work with functions. Manipulation can be more mindful when it is fluent.

A-SSE.1b Fluency in transforming expressions and chunking (seeing parts of an expression as a single object) is essential in factoring, completing the square and other mindful algebraic calculations.

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PARCC MODEL CONTENT FRAMEWORK FOR MATHEMATICS FOR GEOMETRY

Geometry Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 1 and 2. Course emphases are indicated by: ■ Major Content; ■ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

Congruence (G-CO)

- Experiment with transformations in the plane (1, 2, 3, 4, 5)
- Understand congruence in terms of rigid motions (6, 7, 8)
- Prove geometric theorems (9, 10, 11)
- Make geometric constructions (12, 13)

Similarity, Right Triangles, and Trigonometry (G-SRT)

- Understand similarity in terms of similarity transformations (1, 2, 3)
- Prove theorems using similarity (4, 5)
- Define trigonometric ratios and solve problems involving right triangles (6, 7, 8)

Circles (G-C)

- Understand and apply theorems about circles (1, 2, 3)
- Find arc lengths and areas of sectors of circles (5)

Expressing Geometric Properties with Equations (G-GPE)

- Translate between the geometric description and the equation of a conic section (1)
- Use coordinates to prove simple geometric theorems algebraically (4, 5, 6, 7)

Geometric measurement and dimension (G-GMD)

- Explain volume formulas and use them to solve problems (1, 3)
- Visualize relationships between two-dimensional and three-dimensional objects (4)

Modeling with Geometry (G-MG)

Mathematical Practices

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

- Apply geometric concepts in modeling situations (1, 2, 3)

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Examples of Key Advances from Previous Grades or Courses

- Because concepts such as rotation, reflection and translation were treated in the grade 8 standards mostly in the context of hands-on activities, and with an emphasis on geometric intuition, high school Geometry will put equal weight on precise definitions.
- In grades K–8, students worked with a variety of geometric measures (length, area, volume, angle, surface area and circumference). In high school Geometry, students apply these component skills in tandem with others in the course of modeling tasks and other substantial applications (MP.4).
- The skills that students develop in Algebra I around simplifying and transforming square roots will be useful when solving problems that involve distance or area and that make use the Pythagorean theorem.
- In grade 8, students learned the Pythagorean theorem and used it to determine distances in a coordinate system (8.G.6–8). In high school Geometry, students will build on their understanding of distance in coordinate systems and draw on their growing command of algebra to connect equations and graphs of circles (G-GPE.1).
- The algebraic techniques developed in Algebra I can be applied to study analytic geometry. Geometric objects can be analyzed by the algebraic equations that give rise to them. Some basic geometric theorems in the Cartesian plane can be proven using algebra.

Discussion of Mathematical Practices in Relation to Course Content

- **Reason abstractly and quantitatively** (MP.2). Abstraction is used in geometry when, for example, students use a diagram of a specific isosceles triangle as an aid to reason about *all* isosceles triangles (G-CO.9). Quantitative reasoning in geometry involves the real numbers in an essential way: Irrational numbers show up in work with the Pythagorean theorem (G-SRT.8), area formulas often depend (subtly and informally) on passing to the limit and real numbers are an essential part of the definition of dilation (G-SRT.1). The proper use of units can help students understand the effect of dilation on area and perimeter (N-Q.1).
- **Construct viable arguments and critique the reasoning of others** (MP.3). While all of high school mathematics should work to help students see the importance and usefulness of deductive arguments, geometry is an ideal arena for developing the skill of creating and presenting proofs (G-CO.9.10). One reason is that conjectures about geometric phenomena are often about infinitely many cases at once — for example, *every* angle inscribed in a semicircle is a right angle — so that such results cannot be established by checking every case (G-C.2).
- **Use appropriate tools strategically** (MP.5). Dynamic geometry environments can help students look for invariants in a whole class of geometric constructions, and the constructions in such environments can sometimes lead to an idea behind a proof of a conjecture.
- **Attend to precision** (MP.6). Teachers might use the activity of creating definitions as a way to help students see the value of precision. While this is possible in every course, the activity has a particularly visual appeal in geometry. For example, a class can build the definition of *quadrilateral* by starting with a rough idea (“four sides”), gradually refining the idea so that it rules out figures that do not fit the intuitive idea. Another place in geometry where precision is

necessary and useful is in the refinement of conjectures so that initial conjectures that are not correct can be salvaged — two angle measures and a side length do not determine a triangle, but a certain configuration of these parts leads to the angle-side-angle theorem (G-CO.8).

- **Look for and make use of structure (MP.7).** Seeing structure in geometric configurations can lead to insights and proofs. This often involves the creation of auxiliary lines not originally part of a given figure. Two classic examples are the construction of a line through a vertex of a triangle parallel to the opposite side as a way to see that the angle measures of a triangle add to 180 degrees and the introduction of a symmetry line in an isosceles triangle to see that the base angles are congruent (G-CO.9, 10). Another kind of hidden structure makes use of area as a device to establish results about proportions, such as the important theorem (and its converse) that a line parallel to one side of a triangle divides the other two sides proportionally (G-SRT.4).

Fluency Recommendations

- G-SRT.5** Fluency with the triangle congruence and similarity criteria will help students throughout their investigations of triangles, quadrilaterals, circles, parallelism and trigonometric ratios. These criteria are necessary tools in many geometric modeling tasks.
- G-GPE.4, 5, 7** Fluency with the use of coordinates to establish geometric results, calculate length and angle, and use geometric representations as a modeling tool are some of the most valuable tools in mathematics and related fields.
- G-CO.12** Fluency with the use of construction tools, physical and computational, helps students draft a model of a geometric phenomenon and can lead to conjectures and proofs.

PARCC MODEL CONTENT FRAMEWORK FOR MATHEMATICS FOR ALGEBRA II

Algebra II Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 1 and 2. Course emphases are indicated by: ■ Major Content; ■ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

The Real Number System (N-RN)

- Extend the properties of exponents to rational exponents (1, 2)

Quantities* (N-Q)

- Reason quantitatively and use units to solve problems (2)

The Complex Number System (N-CN)

- Perform arithmetic operations with complex numbers (1, 2)
- Use complex numbers in polynomial identities and equations (7)

Seeing Structure in Expressions (A-SSE)

- Interpret the structure of expressions (2)
- Write expressions in equivalent forms to solve problems (3, 4)

Arithmetic with Polynomials and Rational Expressions (A-APR)

- Understand the relationship between zeros and factors of polynomials (2, 3)
- Use polynomial identities to solve problems (4)
- Rewrite rational expressions (6)

Reasoning with Equations and Inequalities (A-REI)

- Understand solving equations as a process of reasoning and explain the reasoning (1, 2)
- Solve equations and inequalities in one variable (4)

Mathematical Practices

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

- Solve systems of equations (6, 7)
- Represent and solve equations and inequalities graphically (11)

Interpreting Functions (F-IF)

- Interpret functions that arise in applications in terms of the context (4, 6)
- Analyze functions using different representations (7, 8, 9)

Building Functions (F-BF)

- Build a function that models a relationship between two quantities (1, 2)
- Build new functions from existing functions (3, 4a)

Linear, Quadratic, and Exponential Models* (F-LE)

- Construct and compare linear, quadratic, and exponential models and solve problems (4)
- Interpret expressions for functions in terms of the situation they model (5)

Trigonometric Functions (F-TF)

- Extend the domain of trigonometric functions using the unit circle (1, 2)
- Model periodic phenomena with trigonometric functions (5)
- Prove and apply trigonometric identities (8)

Expressing Geometric Properties with Equations (G-GPE)

- Translate between the geometric description and the equation for a conic section (2)

Making Inferences and Justifying Conclusions (S-IC)

- Understand and evaluate random processes underlying statistical experiments (1, 2)
- Make inferences and justify conclusions from sample surveys, experiments and observational studies (3, 4, 5, 6)

Conditional Probability and the Rules of Probability (S-CP)

- Understand independence and conditional probability and use them to interpret data (1, 2, 3, 4, 5)
- Use the rules of probability to compute probabilities of compound events in a uniform probability model (6, 7)

Examples of Key Advances from Previous Grades or Courses

- In Algebra I, students added, subtracted and multiplied polynomials. In Algebra II, students divide polynomials with remainder, leading to the factor and remainder theorems. This is the underpinning for much of advanced algebra, including the algebra of rational expressions.
- Themes from middle school algebra continue and deepen during high school. As early as grade 6, students began thinking about solving equations as a process of reasoning (6.EE.5). This perspective continues throughout Algebra I and Algebra II (A-REI).⁴ “Reasoned solving” plays a role in Algebra II because the equations students encounter can have extraneous solutions (A-REI.2).
- In Algebra I, students worked with quadratic equations with no real roots. In Algebra II, they extend the real numbers to complex numbers, and one effect is that they now have a complete theory of quadratic equations: Every quadratic equation with complex coefficients has (counting multiplicities) two roots in the complex numbers.
- In grade 8, students learned the Pythagorean theorem and used it to determine distances in a coordinate system (8.G.6–8). In Geometry, students proved theorems using coordinates (G-GPE.4–7). In Algebra II, students will build on their understanding of distance in coordinate systems and draw on their growing command of algebra to connect equations and graphs of conic sections (e.g., G-GPE.1).
- In Geometry, students began trigonometry through a study of right triangles. In Algebra II, they extend the three basic functions to the entire unit circle.
- As students acquire mathematical tools from their study of algebra and functions, they apply these tools in statistical contexts (e.g., S-ID.6). In a modeling context, they might informally fit an exponential function to a set of data, graphing the data and the model function on the same coordinate axes.

Discussion of Mathematical Practices in Relation to Course Content

While all of the mathematical practice standards are important in all three courses, four are especially important in the Algebra II course:

- **Construct viable arguments and critique the reasoning of others (MP.3).** As in geometry, there are central questions in advanced algebra that cannot be answered definitively by checking evidence. There are important results about *all* functions of a certain type — the factor theorem for polynomial functions, for example — and these require general arguments (A-APR.2). Deciding whether two functions are equal on an infinite set cannot be settled by looking at

⁴ See, for example, “Reasoned Solving,” in *Focus in High School Mathematics: Reasoning and Sense Making* (National Council of Teachers of Mathematics, 2009).

tables or graphs; it requires arguments of a different sort (F-IF.8).

- **Attend to precision (MP.6).** As in the previous two courses, the habit of using precise language is not only a tool for effective communication but also a means for coming to understanding. For example, when investigating loan payments, if students can articulate something like, “What you owe at the end of a month is what you owed at the start of the month, plus $\frac{1}{12}$ of the yearly interest on that amount, minus the monthly payment,” they are well along a path that will let them construct a recursively defined function for calculating loan payments (A-SSE.4).
- **Look for and make use of structure (MP.7).** The structure theme in Algebra I centered on seeing and using the structure of algebraic expressions. This continues in Algebra II, where students delve deeper into transforming expressions in ways that reveal meaning. The example given in the standards — that $x^4 - y^4$ can be seen as the difference of squares — is typical of this practice. This habit of seeing subexpressions as single entities will serve students well in areas such as trigonometry, where, for example, the factorization of $x^4 - y^4$ described above can be used to show that the functions $\cos^4 x - \sin^4 x$ and $\cos^2 x - \sin^2 x$ are, in fact, equal (A-SSE.2).

In addition, the standards call for attention to the structural similarities between polynomials and integers (A-APR.1). The study of these similarities can be deepened in Algebra II: Like integers, polynomials have a division algorithm, and division of polynomials can be used to understand the factor theorem, transform rational expressions, help solve equations and factor polynomials.

- **Look for and express regularity in repeated reasoning (MP.8).** Algebra II is where students can do a more complete analysis of sequences (F-IF.3), especially arithmetic and geometric sequences, and their associated series. Developing recursive formulas for sequences is facilitated by the practice of abstracting regularity for how you get from one term to the next and then giving a precise description of this process in algebraic symbols (F-BF.2). Technology can be a useful tool here: Most Computer Algebra Systems allow one to model recursive function definitions in notation that is close to standard mathematical notation. And spreadsheets make natural the process of taking successive differences and running totals (MP.5).

The same thinking — finding and articulating the rhythm in calculations — can help students analyze mortgage payments, and the ability to get a closed form for a geometric series lets them make a complete analysis of this topic. This practice is also a tool for using difference tables to find simple functions that agree with a set of data.

Algebra II is a course in which students can learn some technical methods for performing algebraic calculations and transformations, but sense-making is still paramount (MP.1). For example, analyzing Heron’s formula from geometry lets one connect the zeros of the expression to the degenerate triangles. As in Algebra I, the modeling practice is ubiquitous in Algebra II, enhanced by the inclusion of exponential and logarithmic functions as modeling tools (MP.4). Computer algebra systems provide students with a tool for modeling all kinds of phenomena, experimenting with algebraic objects (e.g., sequences of polynomials), and reducing the computational overhead needed to investigate many classical and useful areas of algebra (MP.5).

Fluency Recommendations

A-APR.6 This standard sets an expectation that students will divide polynomials with remainder by inspection in simple cases. For example, one can view the rational expression $\frac{x+4}{x+3}$ as

$$\frac{x+4}{x+3} = \frac{(x+3)+1}{x+3} = 1 + \frac{1}{x+3}.$$

A-SSE.2 The ability to see structure in expressions and to use this structure to rewrite expressions is a key skill in everything from advanced factoring (e.g., grouping) to summing series to the rewriting of rational expressions to examine the end behavior of the corresponding rational function.

F-IF.3 Fluency in translating between recursive definitions and closed forms is helpful when dealing with many problems involving sequences and series, with applications ranging from fitting functions to tables to problems in finance.

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Pathway Summary Table: AI – G – All Pathway

Table 1. This table summarizes what will be assessed on PARCC end-of-course assessments. A dot indicates that the standard is assessed in the indicated course. Shaded standards are addressed in more than one course. Algebra I and II are adjacent so as to make the shading continuous, despite being generally taught a year apart.

		CCSSM Standard	A I	A II	G		
Number & Quantity		N-RN.1		▪			
		N-RN.2		▪			
		N-RN.3	▪				
		N-Q.1	▪				
		N-Q.2	▪	▪			
		N-Q.3	▪				
		N-CN.1		▪			
		N-CN.2		▪			
		N-CN.7		▪			
		Algebra		A-SSE.1	▪		
A-SSE.2	▪			▪			
A-SSE.3a	▪						
A-SSE.3b	▪						
A-SSE.3c	▪			▪			
A-SSE.4				▪			
A-APR.1	▪						
A-APR.2				▪			
A-APR.3	▪			▪			
A-APR.4				▪			
A-APR.6				▪			
A-CED.1	▪						
A-CED.2	▪						
A-CED.3	▪						
A-CED.4	▪						
A-REI.1	▪			▪			
A-REI.2				▪			
A-REI.3	▪						
A-REI.4a	▪						
A-REI.4b	▪			▪			
A-REI.5	▪						
A-REI.6	▪			▪			
A-REI.7				▪			
A-REI.10	▪						
A-REI.11	▪			▪			
A-REI.12	▪						
Functions				F-IF.1	▪		
		F-IF.2	▪				
		F-IF.3	▪				
		F-IF.4	▪	▪			
		F-IF.5	▪				
		F-IF.6	▪	▪			
		F-IF.7a	▪				
		F-IF.7b	▪				
		F-IF.7c		▪			
		F-IF.7e		▪			
		F-IF.8a	▪				
		F-IF.8b		▪			
		F-IF.9	▪				
		F-BF.1a	▪	▪			
		F-BF.1b		▪			
		F-BF.2		▪			
		F-BF.3	▪	▪			
		F-BF.4a		▪			
		F-LE.1	▪				
		F-LE.2	▪				
		F-LE.3	▪				
		F-LE.4		▪			
		F-LE.5	▪	▪			
		F-TF.1		▪			
		F-TF.2		▪			
		F-TF.5		▪			
		F-TF.8		▪			
		Geometry		G-CO.1			▪
				G-CO.2			▪
				G-CO.3			▪
				G-CO.4			▪
				G-CO.5			▪
				G-CO.6			▪
G-CO.7					▪		
G-CO.8					▪		
G-CO.9					▪		
G-CO.10					▪		
G-CO.11					▪		
G-CO.12					▪		
G-CO.13					▪		
G-SRT.1					▪		
G-SRT.2					▪		
G-SRT.3					▪		
G-SRT.4					▪		
G-SRT.5					▪		
G-SRT.6					▪		
G-SRT.7					▪		
G-SRT.8					▪		
G-C.1					▪		
G-C.2					▪		
G-C.3					▪		
G-C.5					▪		
G-GPE.1					▪		
G-GPE.2				▪			
G-GPE.4					▪		
G-GPE.5					▪		
G-GPE.6					▪		
G-GPE.7					▪		
G-GMD.1					▪		
G-GMD.3					▪		
G-GMD.4			▪				
G-MG.1			▪				
G-MG.2			▪				
G-MG.3			▪				
Statistics		S-ID.1	▪				
		S-ID.2	▪				
		S-ID.3	▪				
		S-ID.4	▪				
		S-ID.5	▪				
		S-ID.6	▪				
		S-ID.7	▪				
		S-ID.8	▪				
		S-ID.9	▪				
		S-IC.1		▪			
		S-IC.2		▪			
		S-IC.3		▪			
		S-IC.4		▪			
		S-IC.5		▪			
		S-IC.6		▪			
		S-CP.1		▪			
		S-CP.2		▪			
		S-CP.3		▪			
		S-CP.4		▪			
		S-CP.5		▪			
		S-CP.6		▪			
S-CP.7		▪					

Assessment Limits for Standards Assessed on More Than One End-of-Course Test: AI-G-AII Pathway

Table 2. This draft table shows assessment limits for standards assessed on more than one end-of-course test. (These “cross-cutting” standards are visible as shaded cells in Table 1.)

CCSSM Cluster	CCSSM Key	CCSSM Standard	Algebra I Assessment Limits and Clarifications	Algebra II Assessment Limits and Clarifications
Reason quantitatively and use units to solve problems	N-Q.2	Define appropriate quantities for the purpose of descriptive modeling.	This standard will be assessed in Algebra I by ensuring that some modeling tasks (involving Algebra I content or securely held content from grades 6-8) require the student to create a quantity of interest in the situation being described (i.e., a quantity of interest is not selected for the student by the task). For example, in a situation involving data, the student might autonomously decide that a measure of center is a key variable in a situation, and then choose to work with the mean.	This standard will be assessed in Algebra II by ensuring that some modeling tasks (involving Algebra II content or securely held content from previous grades and courses) require the student to create a quantity of interest in the situation being described (i.e., this is not provided in the task). For example, in a situation involving periodic phenomena, the student might autonomously decide that amplitude is a key variable in a situation, and then choose to work with peak amplitude.
Interpret the structure of expressions	A-SSE.2	Use the structure of an expression to identify ways to rewrite it. <i>For example, see $x^4 - y^4$ as $(x^2)^2 - (y^2)^2$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$.</i>	<p>i) Tasks are limited to numerical expressions and polynomial expressions in one variable.</p> <p>ii) Examples: Recognize $53^2 - 47^2$ as a difference of squares and see an opportunity to rewrite it in the easier-to-evaluate form $(53+47)(53-47)$. See an opportunity to rewrite $a^2 + 9a + 14$ as $(a+7)(a+2)$.</p>	<p>i) Tasks are limited to polynomial, rational, or exponential expressions.</p> <p>ii) Examples: see $x^4 - y^4$ as $(x^2)^2 - (y^2)^2$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$. In the equation $x^2 + 2x + 1 + y^2 = 9$, see an opportunity to rewrite the first three terms as $(x+1)^2$, thus recognizing the equation of a circle with radius 3 and center $(-1, 0)$. See $(x^2 + 4)/(x^2 + 3)$ as $((x^2+3) + 1)/(x^2+3)$, thus recognizing an opportunity to write it as $1 + 1/(x^2 + 3)$.</p>
Write expressions in equivalent forms to solve problems	A-SSE.3c	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. [↔] (c) Use the properties of exponents to transform expressions for exponential functions. <i>For example the expression 1.15^t can be rewritten as $(1.15^{1/12})^{12t} \approx 1.012^{12t}$ to reveal the approximate</i>	i) Tasks have a real-world context. As described in the standard, there is an interplay between the mathematical structure of the expression and the structure of the situation such that choosing and producing an equivalent form of the expression reveals something about the situation.	i) Tasks have a real-world context. As described in the standard, there is an interplay between the mathematical structure of the expression and the structure of the situation such that choosing and producing an equivalent form of the expression reveals something about the situation.

CCSSM Cluster	CCSSM Key	CCSSM Standard	Algebra I Assessment Limits and Clarifications	Algebra II Assessment Limits and Clarifications
		<i>equivalent monthly interest rate if the annual rate is 15%.</i>	ii) Tasks are limited to exponential expressions with integer exponents.	ii) Tasks are limited to exponential expressions with rational or real exponents.
Understand the relationship between zeros and factors of polynomials	A-APR.3	Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.	i) Tasks are limited to quadratic and cubic polynomials in which linear and quadratic factors are available. For example, find the zeros of $(x - 2)(x^2 - 9)$.	ii) Tasks include quadratic, cubic, and quartic polynomials and polynomials for which factors are not provided. For example, find the zeros of $(x^2 - 1)(x^2 + 1)$
Understand solving equations as a process of reasoning and explain the reasoning	A-REI.1	Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.	i) Tasks are limited to quadratic equations.	i) Tasks are limited to simple rational or radical equations.
Solve equations and inequalities in one variable	A-REI.4b	Solve quadratic equations in one variable. b) Solve quadratic equations by inspection (e.g., for $x^2 = 49$), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as $a + bi$ for real numbers a and b .	i) Tasks do not require students to write solutions for quadratic equations that have roots with nonzero imaginary parts. However, tasks can require the student to recognize cases in which a quadratic equation has no real solutions. <i>Note, solving a quadratic equation by factoring relies on the connection between zeros and factors of polynomials (cluster A-APR.B). Cluster A-APR.B is formally assessed in A2.</i>	i) In the case of equations that have roots with nonzero imaginary parts, students write the solutions as $a + bi$ for real numbers a and b .
Solve systems of equations	A-REI.6	Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.	i) Tasks have a real-world context. ii) Tasks have hallmarks of modeling as a mathematical practice (less defined tasks, more of the modeling cycle, etc.).	i) Tasks are limited to 3×3 systems.
Represent and solve equations and inequalities graphically	A-REI.11	Explain why the x -coordinates of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation $f(x) = g(x)$; find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and logarithmic functions. *	i) Tasks that assess conceptual understanding of the indicated concept may involve any of the function types mentioned in the standard except exponential and logarithmic functions. ii) Finding the solutions approximately is limited to cases where $f(x)$ and $g(x)$ are	i) Tasks may involve any of the function types mentioned in the standard.

CCSSM Cluster	CCSSM Key	CCSSM Standard	Algebra I Assessment Limits and Clarifications	Algebra II Assessment Limits and Clarifications
			polynomial functions.	
Interpret functions that arise in applications in terms of a context	F-IF.4	For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. <i>Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.</i> *	<p>i) Tasks have a real-world context.</p> <p>ii) Tasks are limited to linear functions, quadratic functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>Compare note (ii) with standard F-IF.7.</i></p> <p><i>The function types listed here are the same as those listed in the Algebra I column for standards F-IF.6 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context</p> <p>ii) Tasks may involve polynomial, exponential, logarithmic, and trigonometric functions.</p> <p><i>Compare note (ii) with standard F-IF.7.</i></p> <p><i>The function types listed here are the same as those listed in the Algebra II column for standards F-IF.6 and F-IF.9.</i></p>
Interpret functions that arise in applications in terms of a context	F-IF.6	Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph. *	<p>i) Tasks have a real-world context.</p> <p>ii) Tasks are limited to linear functions, quadratic functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>The function types listed here are the same as those listed in the Algebra I column for standards F-IF.4 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context.</p> <p>ii) Tasks may involve polynomial, exponential, logarithmic, and trigonometric functions.</p> <p><i>The function types listed here are the same as those listed in the Algebra II column for standards F-IF.4 and F-IF.9.</i></p>
Analyze functions using different representations	F-IF.9	Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions.) <i>For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.</i>	<p>i) Tasks are limited to linear functions, quadratic functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>The function types listed here are the same as those listed in the Algebra I column for standards F-IF.4 and F-IF.6.</i></p>	<p>i) Tasks may involve polynomial, exponential, logarithmic, and trigonometric functions.</p> <p><i>The function types listed here are the same as those listed in the Algebra II column for standards F-IF.4 and F-IF.6.</i></p>
Build a function that models a relationship between two	F-BF.1a	Write a function that describes a relationship between two quantities.* a) Determine an explicit expression, a recursive process, or	<p>i) Tasks have a real-world context.</p> <p>ii) Tasks are limited to linear functions, quadratic functions, and exponential</p>	<p>i) Tasks have a real-world context</p> <p>ii) Tasks may involve linear functions, quadratic functions, and exponential</p>

CCSSM Cluster	CCSSM Key	CCSSM Standard	Algebra I Assessment Limits and Clarifications	Algebra II Assessment Limits and Clarifications
quantities		steps for calculation from a context.	functions with domains in the integers.	functions.
Build new functions from existing functions	F-BF.3	Identify the effect on the graph of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. <i>Include recognizing even and odd functions from their graphs and algebraic expressions for them.</i>	<p>i) Identifying the effect on the graph of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative) is limited to linear and quadratic functions.</p> <p>ii) Experimenting with cases and illustrating an explanation of the effects on the graph using technology is limited to linear functions, quadratic functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p>iii) Tasks do not involve recognizing even and odd functions.</p> <p><i>The function types listed in note (ii) are the same as those listed in the Algebra I column for standards F-IF.4, F-IF.6, and F-IF.9.</i></p>	<p>i) Tasks may involve polynomial, exponential, logarithmic, and trigonometric functions</p> <p>ii) Tasks may involve recognizing even and odd functions.</p> <p><i>The function types listed in note (i) are the same as those listed in the Algebra II column for standards F-IF.4, F-IF.6, and F-IF.9.</i></p>
Interpret expressions for functions in terms of the situation they model	F-LE.5	Interpret the parameters in a linear or exponential function in terms of a context.	<p>i) Tasks have a real-world context.</p> <p>ii) Exponential functions are limited to those with domains in the integers.</p>	<p>i) Tasks have a real-world context.</p> <p>ii) Tasks are limited to exponential functions with domains not in the integers.</p>

Mathematics I Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 3 and 4. Course emphases are indicated by: ■ Major Content; ■ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

Quantities* (N-Q)

- Reason quantitatively and use units to solve problems (1, 2, 3)

Seeing Structure in Expressions (A-SSE)

- Interpret the structure of expressions (1)
- Write expressions in equivalent forms to solve problems (3)

Creating Equations* (A-CED)

- Create equations that describe numbers or relationships (1, 2, 3, 4)

Reasoning with Equations and Inequalities (A-REI)

- Solve equations and inequalities in one variable (3)
- Solve systems of equations (5, 6)
- Represent and solve equations and inequalities graphically (10, 11, 12)

Interpreting Functions (F-IF)

- Understand the concept of a function and use function notation (1, 2, 3)
- Interpret functions that arise in applications in terms of the context (4, 5, 6)
- Analyze functions using different representations (7, 9)

Building Functions (F-BF)

- Build a function that models a relationship between two quantities (1, 2)

Mathematical Practices

- 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.

Linear, Quadratic, and Exponential Models (F-LE)

- Construct and compare linear, quadratic, and exponential models and solve problems (1, 2, 3)
- Interpret expressions for functions in terms of the situation they model (5)

Congruence (G-CO)

- Experiment with transformations in the plane (1, 2, 3, 4, 5, 6, 7, 8)
- Prove geometric theorems (9, 10, 11)

Interpreting categorical and quantitative data (S-ID)

- Summarize, represent, and interpret data on a single count or measurement variable (1, 2, 3)
- Summarize, represent, and interpret data on two categorical and quantitative variables (5, 6)
- Interpret linear models (7, 8, 9)

Examples of Key Advances from Grades K–8

- Students build on previous work with solving linear equations and systems of linear equations in two ways: (a) They extend to more formal solution methods, including attending to the structure of linear expressions, and (b) they solve linear inequalities.
- Students formalize their understanding of the definition of a function, particularly their understanding of linear functions, emphasizing the structure of linear expressions. Students also begin to work on exponential functions, comparing them to linear functions.
- Work with congruence and similarity motions that was begun in grades 6–8 progresses. Students also consider sufficient conditions for congruence of triangles.
- Work with the bivariate data and scatter plots in grades 6–8 is extended to working with lines of best fit.

Discussion of Mathematical Practices in Relation to Course Content

- **Modeling with mathematics** (MP.4) should be a particular focus as students see the purpose and meaning for working with linear and exponential equations and functions.
- **Using appropriate tools strategically** (MP.5) is also important as students explore those models in a variety of ways, including with technology. For example, students might be given a set of data points and experiment with graphing a line that fits the data.
- As Mathematics I continues to develop a foundation for more formal reasoning, students should engage in the practice of **constructing viable arguments and critiquing the reasoning of others** (MP.3).

Fluency Recommendations

- A/G** High school students should become fluent in solving characteristic problems involving the analytic geometry of lines, such as finding the equation of a line given a point and a slope. This fluency can support students in solving less routine mathematical problems involving linearity, as well as in modeling linear phenomena (including modeling using systems of linear inequalities in two variables).
- G** High school students should become fluent in using geometric transformation to represent the relationships among geometric objects. This fluency provides a powerful tool for visualizing relationships, as well as a foundation for exploring ideas both within geometry (e.g., symmetry) and outside of geometry (e.g., transformations of graphs).
- S** Students should be able to create a visual representation of a data set that is useful in understanding possible relationships among variables.

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Mathematics II Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 3 and 4. Course emphases are indicated by: ■ Major Content; ■ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

The Real Number System (N-RN)

- Extend the properties of exponents to rational exponents (1, 2)
- Use properties of rational and irrational numbers (3)

Quantities* (N-Q)

- Reason quantitatively and use units to solve problems (2)

The Complex Number System (N-CN)

- Perform arithmetic operations with complex numbers (1, 2)
- Solve quadratic equations with real coefficients that have complex solutions (7)

Seeing Structure in Expressions (A-SSE)

- Interpret the structure of expressions (1, 2)
- Write expressions in equivalent forms to solve problems (3)

Arithmetic with Polynomials and Rational Expressions (A-APR)

- Perform arithmetic operations on polynomials (1)

Creating Equations* (A-CED)

- Create equations that describe numbers or relationships (1, 2, 4)

Reasoning with Equations and Inequalities (A-REI)

Mathematical Practices

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

- Understand solving equations as a process of reasoning and explain the reasoning (1)
- Solve equations and inequalities in one variable (4)
- Solve systems of equations (7)

Interpreting Functions (F-IF)

- Interpret functions that arise in applications in terms of the context (4, 5, 6)
- Analyze functions using different representations (7, 8, 9)

Building Functions (F-BF)

- Build a function that models a relationship between two quantities (1)
- Build new functions from existing functions (3)

Similarity, Right Triangles, and Trigonometry (G-SRT)

- Understand similarity in terms of similarity transformations (1, 2, 3)
- Prove theorems using similarity (4, 5)
- Define trigonometric ratios and solve problems involving right triangles (6, 7, 8)

Geometric measurement and dimension (G-GMD)

- Explain volume formulas and use them to solve problems (1, 3)

Interpreting categorical and quantitative data (S-ID)

- Summarize, represent, and interpret data on two categorical and quantitative variables (6)

Conditional Probability and Rules of Probability (S-CP)

- Understand independence and conditional probability and use them to interpret data (1, 2, 3, 4, 5)
- Use the rules of probability to compute probabilities of compound events in a uniform probability model (6, 7)

Examples of Key Advances from Mathematics I

- Students extend their previous work with linear and exponential expressions, equations, systems of equations and inequalities to quadratic relationships.
- A parallel extension occurs from linear and exponential functions to quadratic functions, where students also begin to analyze functions in terms of transformations.
- Building on their work with transformations, students produce increasingly formal arguments about geometric relationships, particularly around notions of similarity.

Discussion of Mathematical Practices in Relation to Course Content

- **Modeling with mathematics** (MP.4) should be a particular focus as students see the purpose and meaning for working with quadratic equations and functions, including **using appropriate tools strategically** (MP.5).
- As students explore a variety of ways to represent quadratic expressions, they should **look for and make use of structure** (MP.7).
- As their ability to create and use formal mathematical arguments grows, increased emphasis is placed on students' ability to **attend to precision** (MP.6), as well as to **construct viable arguments and critique the reasoning of others** (MP.3).

Fluency Recommendations

- F/S** Fluency in graphing functions (including linear, quadratic and exponential) and interpreting key features of the graphs in terms of their function rules and a table of value, as well as recognizing a relationship (including a relationship within a data set), fits one of those classes. This forms a critical base for seeing the value and purpose of mathematics, as well as for further study in mathematics.
- A-APR.1** Fluency in adding, subtracting and multiplying polynomials supports students throughout their work in algebra, as well as in their symbolic work with functions. Manipulation can be more mindful when it is fluent.
- G-SRT.5** Fluency with the triangle congruence and similarity criteria will help students throughout their investigations of triangles, quadrilaterals, circles, parallelism and trigonometric ratios. These criteria are necessary tools in geometric modeling.

Mathematics III Overview

Numerals in parentheses designate individual content standards that are eligible for assessment in whole or in part. Underlined numerals (e.g., 1) indicate standards eligible for assessment on two or more end-of-course assessments. For more information, see Tables 3 and 4. Course emphases are indicated by: ■ Major Content; □ Supporting Content; ● Additional Content. Not all CCSSM content standards in a listed domain or cluster are assessed.

Quantities* (N-Q)

- Reason quantitatively and use units to solve problems (2)

Seeing Structure in Expressions (A-SSE)

- Interpret the structure of expressions (2)
- Write expressions in equivalent forms to solve problems (4)

Arithmetic with Polynomials and Rational Expressions (A-APR)

- Understand the relationship between zeros and factors of polynomials (2, 3)
- Use polynomial identities to solve problems (4)
- Rewrite rational expressions (6)

Creating Equations* (A-CED)

- Create equations that describe numbers or relationships (1, 2)

Reasoning with Equations and Inequalities (A-REI)

- Understand solving equations as a process of reasoning and explain the reasoning (1, 2)
- Represent and solve equations and inequalities graphically (11)

Interpreting Functions (F-IF)

- Interpret functions that arise in applications in terms of the context (4, 6)
- Analyze functions using different representations (7, 9)

Mathematical Practices

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

Building Functions (F-BF)

- Build new functions from existing functions (3, 4a)

Linear, Quadratic, and Exponential Models* (F-LE)

- Construct and compare linear, quadratic, and exponential models and solve problems (4)

Trigonometric Functions (F-TF)

- Extend the domain of trigonometric functions using the unit circle (1, 2)
- Model periodic phenomena with trigonometric functions (5)
- Prove and apply trigonometric identities (8)

Congruence (G-CO)

- Make geometric constructions (12, 13)

Circles (G-C)

- Understand and apply theorems about circles (1, 2, 3)
- Find arc lengths and areas of sectors of circles (5)

Expressing Geometric Properties with Equations (G-GPE)

- Translate between the geometric description and the equation of a conic section (1, 2)
- Use coordinates to prove simple geometric theorems algebraically (4, 5, 6, 7)

Geometric Measurement and Dimension (G-GMD)

- Visualize relationships between two-dimensional and three-dimensional objects (4)

Modeling with Geometry (G-MG)

- Apply geometric concepts in modeling situations (1, 2, 3)

Interpreting Categorical and Quantitative Data (S-ID)

- Summarize, represent, and interpret data on a single count or measurement variable (4)

Making Inferences and Justifying Conclusions (S-IC)

- Understand and evaluate random processes underlying statistical experiments (1, 2)
- Make inferences and justify conclusions from sample surveys, experiments and observational studies (3, 4, 5, 6)

DRAFT

Examples of Key Advances from Mathematics II

- Students begin to see polynomials as a system that has mathematical coherence, not just as a set of expressions of a specific type. An analogy to the integers can be made (including operations, factoring, etc.). Subsequently, polynomials can be extended to rational expressions, analogous to the rational numbers.
- The understandings that students have developed with linear, exponential and quadratic functions are extended to considering a much broader range of classes of functions.
- In statistics, students begin to look at the role of randomization in statistical design.

Discussion of Mathematical Practices in Relation to Course Content

- **Modeling with mathematics** (MP.4) continues to be a particular focus as students see a broader range of functions, including **using appropriate tools strategically** (MP.5).
- **Constructing viable arguments and critiquing the reasoning of others** (MP.3) continues to be a focus, as does **attention to precision** (MP.6), because students are expected to provide increasingly precise arguments.
- As students continue to explore a range of algebraic expressions, including polynomials, they should **look for and make use of structure** (MP.7).
- Finally, as students solidify the tools they need to continue their study of mathematics, a focus on **making sense of problems and persevering in solving them** (MP.1) is an essential component for their future success.

Fluency Recommendations

- A/F** Students should look at algebraic manipulation as a meaningful enterprise, in which they seek to understand the structure of an expression or equation and use properties to transform it into forms that provide useful information (e.g., features of a function or solutions to an equation). This perspective will help students continue to usefully apply their mathematical knowledge in a range of situations, whether their continued study leads them toward college or career readiness.
- M** Seeing mathematics as a tool to model real-world situations should be an underlying perspective in everything students do, including writing algebraic expressions, creating functions, creating geometric models and understanding statistical relationships. This perspective will help students appreciate the importance of mathematics as they continue their study of it.
- N-Q** In particular, students should recognize that much of mathematics is concerned with understanding quantities and their relationships. They should pick appropriate units for quantities being modeled, using them as a guide to understand a situation, and be attentive to the level of accuracy that is reported in a solution.
- F-BF.3** Students should understand the effects of parameter changes and be able to apply them to create a rule modeling the function.

Pathway Summary Table: Mathematics I - III

Table 3. This draft table summarizes what will be assessed on PARCC end-of-course assessments. A dot indicates that the standard is assessed in the indicated course. Shaded standards are addressed in more than one course.

	CCSSM Standard	M I	M II	M III	
Number & Quantity	N-RN.1		■		
	N-RN.2		■		
	N-RN.3		■		
	N-Q.1	■			
	N-Q.2	■	■	■	
	N-Q.3	■			
	N-CN.1		■		
	N-CN.2		■		
	N-CN.7		■		
	A-SSE.1a	■			
	A-SSE.1b	■			
	A-SSE.2		■	■	
Algebra	A-SSE.3a		■		
	A-SSE.3b		■		
	A-SSE.3c	■			
	A-SSE.4			■	
	A-APR.1		■		
	A-APR.2			■	
	A-APR.3			■	
	A-APR.4			■	
	A-APR.6			■	
	A-CED.1	■	■	■	
	A-CED.2	■	■	■	
	A-CED.3	■			
	A-CED.4	■	■		
	A-REI.1		■	■	
	A-REI.2			■	
	A-REI.3	■			
	A-REI.4a		■		
	A-REI.4b		■		
	A-REI.5	■			
	A-REI.6	■			
	A-REI.7		■		
	A-REI.10	■			
	A-REI.11	■		■	
	A-REI.12	■			
Functions	F-IF.1	■			
	F-IF.2	■			
	F-IF.3	■			
	F-IF.4	■	■	■	
	F-IF.5	■	■		
	F-IF.6	■	■	■	
	F-IF.7a	■	■		
	F-IF.7b	■	■		
	F-IF.7c	■		■	
	F-IF.7e	■	■	■	
	F-IF.8a	■	■		
	F-IF.8b	■			
	F-IF.9	■	■	■	
	F-BF.1a	■	■		
	F-BF.1b	■	■		
	F-BF.2	■			
	F-BF.3	■	■	■	
	F-BF.4a	■	■		
	F-LE.1a	■			
	F-LE.1b	■			
	F-LE.1c	■			
	F-LE.2	■			
	F-LE.3	■			
	F-LE.4			■	
	F-LE.5	■			
	F-TF.1			■	
	F-TF.2			■	
	F-TF.5			■	
	F-TF.8			■	
	Geometry	G-CO.1	■		
		G-CO.2	■		
		G-CO.3	■		
G-CO.4		■			
G-CO.5		■			
G-CO.6		■			
G-CO.7		■			
G-CO.8		■			
G-CO.9		■			
G-CO.10		■			
G-CO.11		■			
G-CO.12				■	
G-CO.13				■	
G-SRT.1a			■		
G-SRT.1b			■		
G-SRT.2			■		
G-SRT.3			■		
G-SRT.4			■		
G-SRT.5			■		
G-SRT.6			■		
G-SRT.7			■		
G-SRT.8			■		
G-C.1				■	
G-C.2				■	
G-C.3				■	
G-C.5				■	
G-GPE.1				■	
G-GPE.2				■	
G-GPE.4				■	
G-GPE.5				■	
G-GPE.6				■	
G-GPE.7				■	
G-GMD.1		■			
G-GMD.3		■			
G-GMD.4			■		
G-MG.1			■		
G-MG.2			■		
G-MG.3			■		
Statistics	S-ID.1	■			
	S-ID.2	■			
	S-ID.3	■			
	S-ID.4			■	
	S-ID.5	■			
	S-ID.6a	■	■		
	S-ID.6b		■		
	S-ID.6c	■			
	S-ID.7	■			
	S-ID.8	■			
	S-ID.9	■			
	S-IC.1			■	
	S-IC.2			■	
	S-IC.3			■	
	S-ID.4			■	
	S-ID.5			■	
	S-ID.6			■	
	S-CP.1		■		
	S-CP.2		■		
	S-CP.3		■		
	S-CP.4		■		
S-CP.5		■			
S-CP.6		■			
S-CP.7		■			

CCSSM Standard	M I	M II	M III
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Assessment Limits for Standards Assessed on More Than One End-of-Course Test: Mathematics I - III Pathway

Table 4. This draft table shows assessment limits for standards assessed on more than one end-of-course test. (These “cross-cutting” standards are visible as shaded cells in Table 3.)

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
Reason quantitatively and use units to solve problems	N-Q.2	Define appropriate quantities for the purpose of descriptive modeling.	This standard will be assessed in Math I by ensuring that some modeling tasks (involving Math I content or securely held content from grades 6-8) require the student to create a quantity of interest in the situation being described (i.e., a quantity of interest is not selected for the student by the task). For example, in a situation involving data, the student might autonomously decide that a measure of center is a key variable in a situation, and then choose to work with the mean.	This standard will be assessed in Math II by ensuring that some modeling tasks (involving Math II content or securely held content from previous grades and courses) require the student to create a quantity of interest in the situation being described (i.e., a quantity of interest is not selected for the student by the task). For example, in a situation involving volume of a prism or pyramid, the student might autonomously decide that the area of the base is a key variable in a situation, and then choose to work with that dimension to solve the problem.	This standard will be assessed in Math III by ensuring that some modeling tasks (involving Math III content or securely held content from previous grades and courses) require the student to create a quantity of interest in the situation being described (i.e., a quantity of interest is not selected for the student by the task). For example, in a situation involving periodic phenomena, the student might autonomously decide that amplitude is a key variable in a situation, and then choose to work with peak amplitude.
Interpret the structure of expressions	A-SSE.1b	Interpret expressions that represent a quantity in terms of its context. b) Interpret complicated expressions by viewing one or more of their parts as a single entity. <i>For example, interpret $P(1+r)^n$ as the product of P and a factor not depending on P.</i>	i) Tasks are limited to exponential expressions, including related numerical expressions.	i) Tasks are limited to quadratic expressions.	-

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
Interpret the structure of expressions	A-SSE.2	Use the structure of an expression to identify ways to rewrite it. <i>For example, see $x^4 - y^4$ as $(x^2)^2 - (y^2)^2$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$.</i>	-	<p>i) Tasks are limited to quadratic and exponential expressions, including related numerical expressions.</p> <p>ii) Examples: See an opportunity to rewrite $a^2 + 9a + 14$ as $(a+7)(a+2)$. Recognize $53^2 - 47^2$ as a difference of squares and see an opportunity to rewrite it in the easier-to-evaluate form $(53+47)(53-47)$.</p>	<p>i) Tasks are limited to polynomial and rational expressions.</p> <p>ii) Examples: see $x^4 - y^4$ as $(x^2)^2 - (y^2)^2$, thus recognizing it as a difference of squares that can be factored as $(x^2 - y^2)(x^2 + y^2)$. In the equation $x^2 + 2x + 1 + y^2 = 9$, see an opportunity to rewrite the first three terms as $(x+1)^2$, thus recognizing the equation of a circle with radius 3 and center $(-1, 0)$. See $(x^2 + 4)/(x^2 + 3)$ as $((x^2 + 3) + 1)/(x^2 + 3)$, thus recognizing an opportunity to write it as $1 + 1/(x^2 + 3)$.</p>
Create equations that describe numbers or relationships	A-CED.1	Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.	<p>i) Tasks are limited to linear or exponential equations with integer exponents.</p> <p>ii) Tasks have a real-world context.</p> <p>iii) In the linear case, tasks have more of the hallmarks of modeling as a mathematical practice (less defined tasks, more of the modeling cycle, etc.).</p>	<p>i) Tasks are limited to quadratic and exponential equations.</p> <p>ii) Tasks have a real-world context.</p> <p>iii) In simpler cases (such as exponential equations with integer exponents), tasks have more of the hallmarks of modeling as a mathematical practice (less defined tasks, more of the modeling cycle, etc.).</p>	<p>i) Tasks are limited to simple rational or exponential equations</p> <p>ii) Tasks have a real-world context.</p>
Create equations that describe numbers or relationships	A-CED.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales	<p>i) Tasks are limited to linear equations</p> <p>ii) Tasks have a real-world context.</p> <p>iii) Tasks have the hallmarks of modeling as a mathematical practice (less defined tasks, more</p>	<p>i) Tasks are limited to quadratic equations</p> <p>ii) Tasks have a real-world context.</p> <p>iii) Tasks have the hallmarks of modeling as a mathematical practice (less defined tasks, more</p>	<p>i) Tasks are limited to simple polynomial, rational, or exponential equations</p> <p>ii) Tasks have a real-world context.</p>

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
			of the modeling cycle, etc.).	of the modeling cycle, etc.).	
Create equations that describe numbers or relationships	A-CED.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law $V = IR$ to highlight resistance R .	<ul style="list-style-type: none"> i) Tasks are limited to linear equations ii) Tasks have a real-world context. 	<ul style="list-style-type: none"> i) Tasks are limited to quadratic equations ii) Tasks have a real-world context. 	-
Understand solving equations as a process of reasoning and explain the reasoning	A-REI.1	Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.	-	<ul style="list-style-type: none"> i) Tasks are limited to quadratic equations. 	<ul style="list-style-type: none"> i) Tasks are limited to simple rational or radical equations.
Represent and solve equations and inequalities graphically	A-REI.11	Explain why the x-coordinates of the points where the graphs of the equations $y=f(x)$ and $y=g(x)$ intersect are the solutions of the equation $f(x)=g(x)$; find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where $f(x)$ and/or $g(x)$ are linear, polynomial, rational, absolute value, exponential, and	<ul style="list-style-type: none"> i) Tasks that assess conceptual understanding of the indicated concept may involve any of the function types mentioned in the standard except exponential and logarithmic functions. ii) Finding the solutions approximately is limited to cases where $f(x)$ and $g(x)$ are polynomial. 	-	<ul style="list-style-type: none"> i) Tasks may involve any of the function types mentioned in the standard.

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
		logarithmic functions.			
Interpret functions that arise in applications in terms of the context	F-IF.4	For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the of the relationship. <i>Key features include; intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimum; symmetries; end behavior; and periodicity.</i> *	<p>i) Tasks have a real-world context. ii) Tasks are limited to linear functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>The function types listed here are the same as those listed in the Math I column for standards F-IF.6 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context. ii) Tasks are limited to quadratic and exponential functions.</p> <p><i>The function types listed here are the same as those listed in the Math II column for standards F-IF.6 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context. ii) Tasks may involve polynomial, logarithmic, and trigonometric functions.</p> <p><i>The function types listed here are the same as those listed in the Math III column for standards F-IF.6 and F-IF.9.</i></p>
Interpret functions that arise in applications in terms of the context	F-IF.5	Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. <i>For example, if the function $h(n)$ gives the number of person-hours it takes to assemble n engines in a factory, then the positive integers would be an appropriate domain for the function.</i>	<p>i) Tasks have a real-world context. ii) Tasks are limited to linear functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p>	<p>i) Tasks have a real-world context. ii) Tasks are limited to quadratic functions.</p>	-

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
Interpret functions that arise in applications in terms of the context	F-IF.6	Calculate and interpret the average rate of change of a function (presented symbolically or as a table) or a specified interval. Estimate the rate of change from a graph.	<p>i) Tasks have a real-world context. ii) Tasks are limited to linear functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>The function types listed here are the same as those listed in the Math I column for standards F-IF.4 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context. ii) Tasks are limited to quadratic and exponential functions.</p> <p><i>The function types listed here are the same as those listed in the Math II column for standards F-IF.4 and F-IF.9.</i></p>	<p>i) Tasks have a real-world context. ii) Tasks may involve polynomial, logarithmic, and trigonometric functions.</p> <p><i>The function types listed here are the same as those listed in the Math III column for standards F-IF.4 and F-IF.9.</i></p>
Analyze functions using different representations	F-IF.7a	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. * a) Graph linear and quadratic functions and show intercepts, maxima, and minima.	i) Tasks are limited to linear functions.	i) Tasks are limited to quadratic functions.	-
Analyze functions using different representations	F-IF.7e	Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. * e) graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing	-	i) Tasks are limited to exponential functions.	i) Tasks are limited to logarithmic and trigonometric functions.

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
		period, midline, and amplitude.			
Analyze functions using different representations	F-IF.9	Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions.) <i>For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.</i>	<p>i) Tasks have a real-world context. ii) Tasks are limited to linear functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions with domains in the integers.</p> <p><i>The function types listed here are the same as those listed in the Math I column for standards F-IF.4 and F-IF.6.</i></p>	<p>i) Tasks are limited to on quadratic and exponential functions. ii) Tasks do not have a real-world context.</p> <p><i>The function types listed here are the same as those listed in the Math II column for standards F-IF.4 and F-IF.6.</i></p>	<p>i) Tasks have a real-world context. ii) Tasks may involve polynomial, logarithmic, and trigonometric functions.</p> <p><i>The function types listed here are the same as those listed in the Math III column for standards F-IF.4 and F-IF.6.</i></p>
Build a function that models a relationship between two quantities	F-BF.1a	Write a function that describes a relationship between two quantities.* a) Determine an explicit expression, a recursive process, or steps for a calculation from a context	<p>i) Tasks have a real-world context. ii) Tasks are limited to linear functions and exponential functions with domains in the integers.</p>	<p>i) Tasks have a real-world context. ii) Tasks may involve linear functions, quadratic functions, and exponential functions.</p>	-
Build new functions from existing functions	F-BF.3	Identify the effect on the graph of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. <i>Include</i>	-	<p>i) Identifying the effect on the graph of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$, and $f(x+k)$ for specific values of k (both positive and negative) is limited to linear and quadratic functions. ii) Experimenting with cases and</p>	<p>i) Tasks are limited to polynomial, logarithmic, and trigonometric functions. ii) Tasks may involve recognizing even and odd functions.</p> <p><i>The function types listed in note (i)</i></p>

CCSSM Cluster	CCSSM Key	CCSSM Standard	Mathematics I Assessment Limits and Clarifications	Mathematics II Assessment Limits and Clarifications	Mathematics III Assessment Limits and Clarifications
		<i>recognizing even and odd functions from their graphs and algebraic expressions for them.</i>		<p>illustrating an explanation of the effects on the graph using technology is limited to linear functions, quadratic functions, square root functions, cube root functions, piecewise-defined functions (including step functions and absolute value functions), and exponential functions.</p> <p>iii) Tasks do not involve recognizing even and odd functions.</p> <p><i>The function types listed in note (ii) are the same as those listed in the Math I and Math II columns for standards F-IF.4, F-IF.6, and F-IF.9.</i></p>	<i>are the same as those listed in the Math III column for standards F-IF.4, F-IF.6, and F-IF.9.</i>
Summarize, represent, and interpret data on two categorical and quantitative variables	S-ID.6a	<p>Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.</p> <p>a) Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.</p>	<p>i) Tasks have real-world context.</p> <p>ii) Tasks are limited to linear functions and exponential functions.</p>	<p>i) Tasks have real-world context.</p> <p>ii) Tasks are limited to quadratic functions.</p>	-

The following discussion is a general analysis of the high school standards that bears on all course and is independent of any particular organization of the standards into courses.

Examples of Opportunities for Connections among Standards, Clusters, Domains or Conceptual Categories

- The standards identify a number of connections among conceptual categories.
 - *Connections among Algebra, Functions and Modeling.* Expressions can define functions; determining an output value for a particular input sometimes involves evaluating an expression. Equivalent expressions on the same domain define the same function. Asking when two different functions have the same value for the same input leads to an equation (e.g., for what x does $x^3 = 2x + 5$?); graphing the two functions allows for finding approximate solutions of the equation. Converting a verbal description to an equation, inequality or system of these is an essential skill in modeling. Because functions often describe relationships among quantities, they are frequently used in modeling. Sometimes functions are defined by a recursive process, which can be modeled effectively using a spreadsheet or other technology.
 - *Connections between Geometry and Algebra.* The correspondence between numerical coordinates and geometric points allows methods from algebra to be applied to geometry and vice versa. The solution set of an equation becomes a geometric curve, making visualization a tool for doing and understanding algebra. Geometric shapes can be described by equations, making algebraic manipulation a tool for geometric understanding, modeling and proof. Geometric transformations provide examples of how the notion of function can be used in geometric contexts; conversely, the effect of replacing $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$ and $f(x + k)$ for specific positive and negative values of k can be interpreted geometrically in terms of transformations on the graphs of the functions.
 - *Connections among Statistics, Functions and Modeling.* Functions may be used to describe data; if the data suggest a linear relationship, the relationship can be modeled with a regression line, and its strength and direction can be expressed through a correlation coefficient.
- The standards also identify a number of connections among standards, clusters and domains.
 - *Connections among standards within Algebra and Functions.* A solid understanding of the correspondence between an equation in two variables and its Cartesian graph is the underpinning for the techniques for graphing lines and quadratics, and it helps students understand what is meant by the “graph of a function.” Creating equations and building functions helps students interpret these same objects.

- *Connections among standards within Geometry.* The progression from congruence to area to similarity can be used to put each of these topics on a logical footing: The basic assumptions that congruent figures have the same area and that area is invariant under finite dissection bring coherence to the formulas for calculating areas of polygonal regions. These formulas, along with results such as the fact that triangles with equal bases and heights have the same area, can be used to prove properties of dilations and similarity. The triangle similarity criteria are necessary to develop the trigonometry of right triangles.
- *Connections among standards within Statistics and Probability and Functions.* Study of linear associations in statistics and probability (S-ID.6c, 7) builds on students' understanding of linear relationships (cf. F-LE.1). Exploration of quadratic relationships in data on two measurement variables (S-ID.6) depends on understanding key features of a quadratic function and being able to interpret them in terms of a context (F-IF.4).

Examples of Opportunities for Connecting Mathematical Content and Mathematical Practices

- When students use algebra and functions to model a situation, the symbolic calculations they use and the conclusions they draw from those calculations are examples of decontextualizing and contextualizing (reasoning abstractly and quantitatively, MP.2). For example, students looking for a general method of comparing two rate plans with different rates and startup costs ($R_1 = ax + b$, $R_2 = cx + d$) might find the crossover point by working symbolically to solve the equation $ax + b = cx + d$, obtaining the formal solution $x_{\text{crossover}} = (d - b)/(a - c)$. Still thinking symbolically, students can notice that the expression for $x_{\text{crossover}}$ is undefined when $a = c$. Returning to the context, students can see that this makes sense: Two rate plans with the same rate never cross; the better plan in this case is always the one with the lower startup cost. Returning again to the symbolic equation, students can see that in the case of equal rates ($a = c$), the equation for the crossover point reduces to $b = d$, an equation that is true for all x if and only if the two plans have the same startup cost ... in which case they are the same plan.
- When students transform expressions purposefully, they are looking for and making use of structure (MP.7).
- When modeling a situation, students often can get started by working repetitively with numerical examples and then look for and express regularity in that repeated reasoning by writing equations or functions (MP.8).
- Throughout high school, students construct viable arguments and critique the reasoning of others (MP.3). As in geometry, important questions in advanced algebra cannot be answered definitively by checking evidence. Results about all objects of a certain type — the factor theorem for polynomials, for example — require general arguments. And deciding whether two functions are equal on an infinite set cannot be settled by looking at tables or graphs; it requires a deeper argument.
- Capturing a situation with precise language (MP.6) can be a critical step toward modeling that situation mathematically. For example, when investigating loan payments, if students can

articulate something like, “What you owe at the end of a month is what you owed at the start of the month, plus $\frac{1}{12}$ of the yearly interest on that amount, minus the monthly payment,” they are well along a path that will let them construct a recursively defined function for calculating loan payments.

- There are many opportunities in high school to use appropriate tools strategically (MP.5). For example:
 - Students might use graphing calculators or software to gain understanding of the important fact that the graph of an equation in two variables often forms a curve (which could be a line) (A-REI.10). Students might also use graphing calculators and/or graphing software to gain understanding of the important technique of looking for solutions to equations of the form $f(x) = g(x)$ by graphing the solutions of the equations $y = f(x)$ and $y = g(x)$ in the coordinate plane and looking for intersections of the graphs (A-REI.11).
 - Students might use graphing calculators or software to experiment with cases of replacing a function $f(x)$ by $f(x) + k$, $k f(x)$, $f(kx)$ and $f(x + k)$ for specific positive and negative values of k (F-BF.3).
 - Students might use spreadsheets or similar technology in modeling situations to compute and display recursively defined functions (e.g., a function that gives the balance B_n on a credit card after n months given the interest rate, starting balance and regular monthly payment) (F-BF.1a; F-LE).
 - Students might use a computer algebra system to transform or experiment with algebraic expressions (A-APR.6).
 - When making mathematical models, technology is valuable for varying assumptions, exploring consequences and comparing predictions with data (Common Core State Standards, page 72).
 - Technology is usually necessary to work effectively with large data sets or with simulations having many iterations.

As students progress in mathematics, they learn techniques that are valuable in a variety of settings. For example, the quadratic formula is a tool in the student’s toolkit once it has ceased to become the target of instruction in itself. From then on, it is readily available to the student for use in applications or in reasoning about quadratic equations.

PARCC MODEL CONTENT FRAMEWORKS FOR MATHEMATICS

ADDITIONAL NOTE ON MODELING (MP.4)

Modeling is a conceptual category in high school (pages 72 and 73 of *Common Core State Standards for Mathematics*) as well as a practice standard (MP.4). The practice standard for modeling reads in part as follows:

In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another.

According to this description, numerical or algebraic word problems can be considered modeling tasks when the emphasis is on using mathematics to understand or reason about the context. However, the quoted text also describes an arc across the grades. During middle grades and certainly by high school, tasks with a strong modeling component will have more of the hallmarks that are described on pages 72 and 73 of the standards, such as a need to attend to issues of precision, a need to select relevant variables, engagement in the steps in the modeling cycle or opportunities to use technology.

APPENDIX A: LASTING ACHIEVEMENTS IN K–8⁵

Most of the K–8 content standards trace explicit steps $A \rightarrow B \rightarrow C$ in a progression. This can sometimes make it seem as if any given standard exists only for the sake of the next one in the progression. There are, however, culminating or capstone standards (sometimes called “pinnacles”) – most of them in the middle grades – that remain important far beyond the particular grade level in which they appear. This is signaled in the standards themselves (page 84):

The evidence concerning college and career readiness shows clearly that the knowledge, skills, and practices important for readiness include a great deal of mathematics prior to the boundary defined by (+) symbols in these standards. Indeed, some of the highest priority content for college and career readiness comes from grades 6–8. This body of material includes powerfully useful proficiencies such as applying ratio reasoning in real-world and mathematical problems, computing fluently with positive and negative fractions and decimals, and solving real-world and mathematical problems involving angle measure, area, surface area, and volume. Because important standards for college and career readiness are distributed across grades and courses, systems for evaluating college and career readiness should reach as far back in the standards as grades 6–8. It is important to note as well that cut scores or other information generated by assessment systems for college and career readiness should be developed in collaboration with representatives from higher education and workforce development programs, and should be validated by subsequent performance of students in college and the workforce.

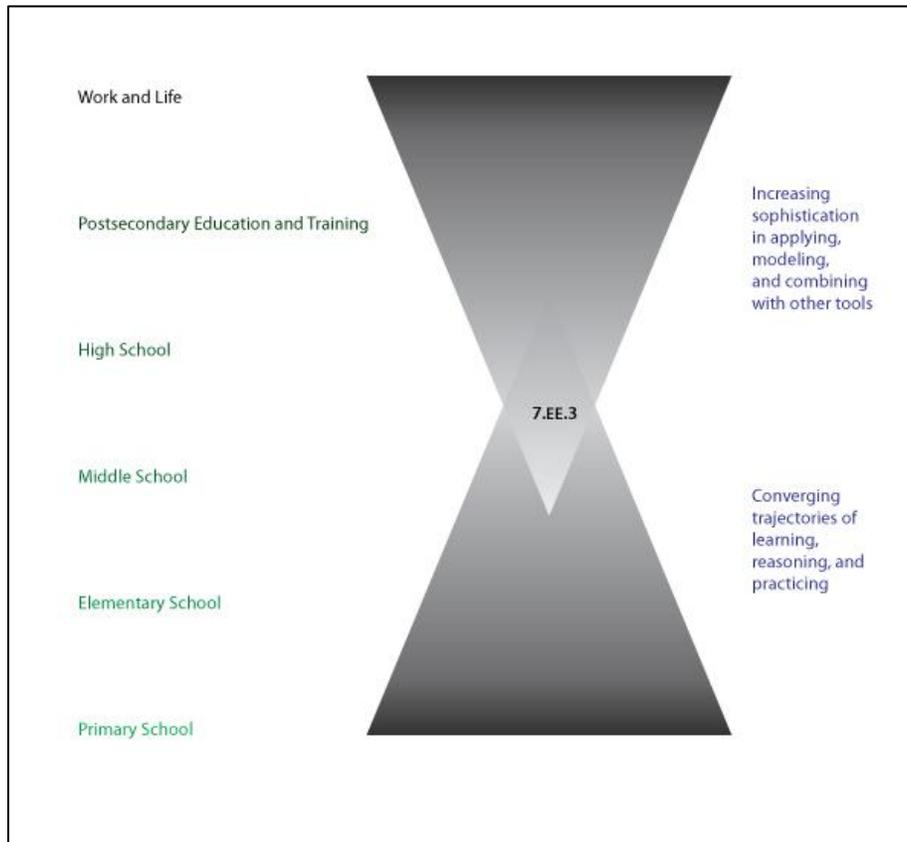
One example of a standard that refers to skills that remain important well beyond middle school is 7.EE.3:

Solve multistep real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. For example: If a woman making \$25 an hour gets a 10% raise, she will make an additional $\frac{1}{10}$ of her salary an hour, or \$2.50, for a new salary of \$27.50. If you want to place a towel bar $9\frac{3}{4}$ inches long in the center of a door that is $27\frac{1}{2}$ inches wide, you will need to place the bar about 9 inches from each edge; this estimate can be used as a check on the exact computation.

Other lasting achievements from K–8 would include working with proportional relationships and unit rates (6.RP.3; 7.RP.1, 2); working with percentages (6.RP.3e; 7.RP.3); and working with area, surface area and volume (7.G.4, 6).

As indicated in the quotation from the standards, skills like these are crucial tools for college, work and life. They are not meant to gather dust during high school but are meant to be applied in increasingly flexible ways, for example to meet the high school standards for Modeling. The illustration below shows how these skills fit in with both the learning progressions in the K–8 standards and the demands of the high school standards and readiness for careers and a wide range of college majors.

⁵ Excerpted from <http://commoncoretools.wordpress.com/2011/06/15/essay-by-jason-zimba-on-pinnacle-standards/>.



As shown in the figure, standards like 7.EE.3 are best thought of as descriptions of component skills that will be applied flexibly during high school in tandem with others in the course of modeling tasks and other substantial applications. This aligns with the demands of postsecondary education for careers and for a wide range of college majors. Thus, when students work with these skills in high school, they are not working below grade level, nor are they reviewing. Applying securely held mathematics to open-ended problems and applications is a *higher-order* skill valued by colleges and employers alike.

APPENDIX B: STARTING POINTS FOR TRANSITION TO THE COMMON CORE STATE STANDARDS

Identified in this section are a few particularly rich areas of mathematical content that can be used by assessment designers, teachers, principals, state and district staff members, and teacher educators as starting points to coordinate and concentrate efforts to transition to the Common Core State Standards. Special attention should be given to how well current materials treat these areas. Organizing implementation work according to progressions is recommended because the instructional approach to any given topic should be informed by its place in an overall flow of ideas. Many of these same areas are the focus of the item prototyping currently under way as part of the development of the PARCC Assessment System.

Please note that particular mathematical practices with which to begin are not listed because doing so may unintentionally lead to a misunderstanding of the nature of mathematical practice itself. The mathematical practices are neither a to-do list nor like filing cabinets into which one can sort behaviors. When a student working on a real-world geometry problem in class questions whether another student's drawing is precise enough, the question involves issues of precision as well as modeling, not to mention communication and argument. In short, a single classroom question or behavior might reflect several practices at once.

The following suggestions are not meant to reorganize the standards into a new structure. In fact, a glance will show that the list is incomplete. By providing a focused list of suggested starting points, the risk of taking on too much and doing none of it well is minimized.

- Counting and Cardinality and Operations and Algebraic Thinking (particularly in the development of an understanding of quantity): grades K–2.
- Operations and Algebraic Thinking: multiplication and division in grades 3–5, tracing the evolving meaning of multiplication from equal groups and array/area thinking in grade 3 to all multiplication situations in grade 4 (including multiplicative comparisons) and from whole numbers in grade 3 to decimals and fractions in grades 5 and 6.
- Number and Operations in Base Ten: addition and subtraction in grades 1–4.
- Number and Operations in Base Ten: multiplication and division in grades 3–6.
- Number and Operations – Fractions: fraction addition and subtraction in grades 4–5, including related development of fraction equivalence in grades 3–5.
- Number and Operations – Fractions: fraction multiplication and division in grades 4–6.
- The Number System: grades 6–7.
- Expressions and Equations: grades 6–8, including how this extends prior work in arithmetic.
- Ratio and Proportional Reasoning: its development in grades 6–7, its relationship to functional thinking in grades 6–8, and its connection to lines and linear equations in grade 8.
- Geometry: work with the coordinate plane in grades 5–8, including connections to ratio,

proportion, algebra and functions in grades 6–high school.

- Geometry: congruence and similarity of figures in grades 8–high school, with emphasis on real-world and mathematical problems involving scales and connections to ratio and proportion.
- Modeling: focused on equations and inequalities in high school, development from simple modeling tasks such as word problems to richer, more open-ended modeling tasks.
- Seeing Structure in Expressions: from expressions appropriate to grades 8–9 to expressions appropriate to grades 10–11.
- Statistics and Probability: comparing populations and drawing inferences in grades 6–high school.
- Units as a cross-cutting theme in the areas of measurement, geometric measurement, base-ten arithmetic, unit fractions and fraction arithmetic, including the role of the number line.

Many of these stressed areas are likely to be glossed over as “something that is already in the curriculum” — yet the standards require more. ***As noted in the standards, these or any content areas are best approached in the ways envisioned by the Standards for Mathematical Practice.*** The reason for greater focus is to give students and teachers more time — time to discuss, reason with, reflect upon and practice mathematics. These identified areas of mathematics are sufficiently rich to allow the mathematical practices to come alive.

The standards are a challenging vision for higher mathematics performance. By suggesting starting points, the aim is in part to define some content boundaries to help focus the innovation in the creation of new materials and to drive innovation in assessment items.

APPENDIX C: RATIONALE FOR THE GRADES 3–8 AND HIGH SCHOOL CONTENT EMPHASES BY CLUSTER

A close reading of the standards turns up many surface features and concrete details that speak to the standards' emphases. These features and details show some of the ways in which the standards are designed to foster greater focus and coherence in mathematics instruction. For example:

The content domains vary from grade to grade. This is perhaps the most obvious structural feature of the content standards. Traditionally, state standards for mathematics have been organized into content strands that are worded identically for every grade K–8 (if not K–12). By contrast, the content domains in Common Core State Standards vary. This communicates immediately that content emphases shift across the grade bands.

Some content domains are more specific than the traditional content strands.

- Number and Operations in Base Ten (NBT), Number and Operations — Fractions (NF) and The Number System (NS) are all top-level domains. Traditionally, these are often substrands within a larger category such as Number and Operations.
- Expressions and Equations (EE) and Functions (F) are both top-level domains. Traditionally, these have both belonged to a larger category such as Patterns, Functions and Algebra. Ratios and Proportional Relationships is a top-level domain in middle school, whereas this work is usually categorized under Patterns, Functions and Algebra (or under several strands).

Domain names with greater specificity tend to concentrate attention more directly on the priorities of the grade. In the rare case when a state has set priorities, it has been done using framing language; here is a quote from the 2001 *Massachusetts Mathematics Curriculum Framework*:

Mathematics in the middle school centers on understanding and computing with rational numbers, and on the study of ratio and proportion (what they are and how they are used to solve problems).

This language states with admirable clarity two of the main priorities for middle school. However, those two priorities are not major headings in the framework itself — so it is easy for them to become lost in the list of discrete grade-level requirements. By contrast, the Common Core State Standards make both of these priorities inescapable using the top-level domain structure (NS and RP).

Some domains are **not** more specific than the traditional strands. The grades K–8 domains of Geometry (G), Measurement and Data (MD), and Statistics and Probability (SP) are no more specific than usual. To the extent that greater specificity in top-level categories suggests greater concentration and emphasis, generality in top-level categories suggests comparatively less concentration and emphasis.

Arithmetic accounts for more than three out of five domains in grades K–5. In the traditional picture of content strands, at most two of four strands involve substantial work in arithmetic in early grades: Number and Operations and, to a lesser extent, Algebra. That would tend to suggest that arithmetic in early grades is no more important than the rest of what happens in mathematics in early grades — perhaps even less important, as the Algebra strand traditionally includes a great deal of work outside of

arithmetic (e.g., work in extending patterns). But in the early grades of the Common Core State Standards, three out of five domains are almost wholly concerned with arithmetic.⁶ Thus, arithmetic is immediately positioned as a supermajority of instruction at the top level of the content organization.

Work in other K–5 domains also supports arithmetic. Further indications of the strong focus on arithmetic can be seen not only in the obvious domains of Counting and Cardinality (CC), Operations and Algebraic Thinking (OA), NBT and NF but also in other domains. For example, standards relating to area and volume explicitly refer to addition, multiplication and their properties (see 3.MD.7 and 5.MD.5). Also, standards for data representation contain a number of explicit references to major themes in arithmetic. For example, standard 2.MD.10 reads:

Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.

The explicit mention of specific, grade-appropriate word problems is not typical of traditional state standards belonging to the Statistics, Data Analysis and Probability strand. That 2.MD.10 does make such explicit references means that it would be a substantial misinterpretation of this standard to say simply that it is “a standard about picture graphs and bar graphs,” as such standards have typically come to be known. Rather, this standard orients picture graphs and bar graphs toward the major work of grade 2. (See Table 1 of the *Progression* for K–3 Categorical Data and 2–5 Measurement Data for further connections of this kind.)

As another example, the word *pattern* first appears in the content standards in grade 3 with standard 3.OA.9:

Identify arithmetic patterns (including patterns in the addition table or multiplication table), and explain them using properties of operations.

The terms *arithmetic*, *addition*, *multiplication* and *properties of operations* do not typically appear in state standards that are “about patterns.” That all of these terms do appear in 3.OA.9 makes it a substantial misinterpretation of this standard to say simply that it is “a standard about patterns,” as such standards have come to be known. Rather, the standard directs patterns toward the larger purposes of the OA domain. The word *pattern* also appears in the Standards for Mathematical Practice (MP.7), and just as with 3.OA.9, every example given in the practice standard again portrays patterns

⁶ The term *arithmetic* is not being used here to mean computation of sums, differences, products and quotients. That is one important part of arithmetic. But arithmetic in the standards is a large and rich subject that equally involves conceptual understanding, procedural skill and fluency, and problem solving with the basic operations. Moreover, the standards progressions in arithmetic are crafted in such a way as to build a sturdy foundation for algebra in middle school. From the “Progression in Operations and Algebraic Thinking” (May 29, 2011, draft, page 2): “The Progression in Operations and Algebraic Thinking deals with the basic operations—the kinds of quantitative relationships they model and consequently the kinds of problems they can be used to solve as well as their mathematical properties and relationships. Although most of the standards organized under the OA heading involve whole numbers, the importance of the Progression is much more general because it describes concepts, properties, and representations that extend to other number systems, to measures, and to algebra. For example, if the mass of the sun is x kilograms, and the mass of the rest of the solar system is y kilograms, then the mass of the solar system as a whole is the sum $x + y$ kilograms. In this example of additive reasoning, it doesn’t matter whether x and y are whole numbers, fractions, decimals, or even variables. Likewise, a property such as distributivity holds for all the number systems that students will study in K–12, including complex numbers.”

(and more generally structure) being put to some use, instead of forming a separate object of study that detracts from focus.

Some clusters are explicitly connected to others; some clusters stand more alone. Some clusters in any given grade naturally stand somewhat apart from others. Examples of these would include:

- Many Geometry clusters, such as those relating to hierarchies of shapes, congruence or similar subjects. These are typically connected more weakly to arithmetic clusters than arithmetic clusters are connected to each other.
- The first cluster in 6.SP, “Develop understanding of statistical variability.” This introduces into the standards the statistical notions of variability and distribution, center and spread. These are, strictly speaking, not mathematical ideas,⁷ so it is natural that they do not connect tightly to, say, applying properties of operations to generate equivalent expressions.
- The Statistics and Probability clusters in 7.SP, which introduce into the standards the notions of randomness, probability, random sampling and comparison of populations.

This is not to say that one might not devise connections to these clusters, if desired; rather it is to say that in other cases, connections are explicit and unavoidable in the standards. For example, 6.EE.9 ties its cluster explicitly to 6.RP; 7.G.1 ties its cluster explicitly to 7.RP; and 8.SP.3 ties its cluster explicitly to 8.F.

A close reading of the *Progressions* also turns up some surface features and concrete details that shed light on some emphases in the standards. Some clusters receive more extensive discussion than others. For example, consider the three clusters in grade 4 OA:

Use the four operations with whole numbers to solve problems.

Gain familiarity with factors and multiples.

Generate and analyze patterns.

Standards are not traditionally written at “uniform grain size” but are often interpreted as such. Some things are quick to state but take a long time in the classroom; others take many words to describe but are simpler to address instructionally. One might have inferred that each of these three clusters was intended to have equal emphasis at grade 4. However, a careful reading of the full body of OA standards dispels this notion. So does even a superficial reading of the *Progression* for OA. There, for instance, we find that:

- Three times as many references are made to standards in the first cluster as are made to standards in the next two clusters combined (6-1-1);

⁷ From the Guidelines for Assessment and Introduction in Statistics Education project report, section on “The Difference between Statistics and Mathematics,” page 6: “A major objective of statistics education is to help students develop statistical thinking. Statistical thinking, in large part, must deal with this omnipresence of variability; statistical problem solving and decision making depend on understanding, explaining and quantifying the variability in the data. It is this focus on variability in data that sets apart statistics from mathematics.”

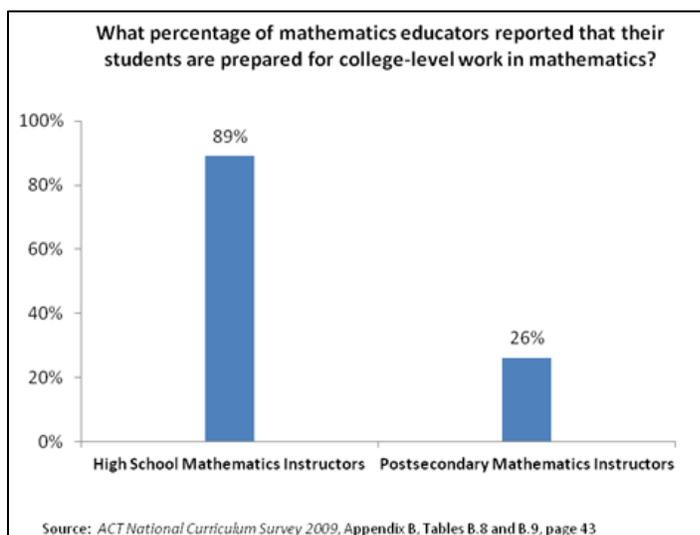
- Four additional references are made to standards in other domains that connect directly to standards in the first cluster, while no such additional references are made in either of the next two clusters (4-0-0);
- More words are used to explain the standards in the first cluster than are used to explain the standards in the next two clusters combined; and
- Both of the illustrative problems provided in the margin relate directly to the first cluster, while no effort was expended on providing illustrative problems that relate directly to either of the next two clusters.

These visible details — any of which, in principle, might have gone the other way — begin to reveal the relative emphases in the standards.

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APPENDIX D: CONSIDERATIONS FOR COLLEGE AND CAREER READINESS

For this draft of the Model Content Frameworks cluster-level emphases have been provided to help ensure that implementation efforts preserve the focus and coherence of the standards. General guidance is provided in this appendix about these emphases in relation to college and career readiness.



Surveys have shown repeatedly that high school mathematics instructors and postsecondary mathematics instructors tend to differ in their views about the importance of particular knowledge and skills as prerequisites for success in entry-level, credit-bearing college mathematics courses (ACT 2006, 2009). When postsecondary instructors in these surveys are asked to rate the importance of various mathematics topics to college readiness, they tend to make sharper distinctions than do high school instructors. Postsecondary instructors in these surveys tend to value mastery of fundamentals over broad topic coverage.

This sentiment has been echoed during PARCC's ongoing discussions with higher education stakeholders. In those discussions, postsecondary instructors have stressed the importance of deeper learning of fundamental mathematics. That includes being able to approach problems in the ways described in the Standards for Mathematical Practice. Postsecondary instructors also stressed the importance of being able to solve complex problems using securely held knowledge and skills. The ability to flexibly apply what one already knows to a nonroutine or complex problem is an important aspect of readiness for college and careers.⁸ Although PARCC's stakeholder discussions do not themselves have the scientific weight of a well-designed national survey, it is reassuring to see the same themes reinforced in both settings.

Educators in high school can help bridge this gap. To that end, educators can devote particular energy to the following aspects of the standards, which play a prominent role in college and career readiness:

- The Standards for Mathematical Practice, viewed in connection with mathematical content.
- Modeling and rich applications (see pages 72 and 73 in the standards), which can be integrated into mathematics curriculum, instruction and assessment.
 - Note in particular the standards in high school marked with a star symbol (★). Star symbols identify potential opportunities to integrate content with the modeling practice.
 - Note also that modeling is a sophisticated practice; this means that modeling and other

⁸ See also "Appendix A: Lasting Achievements in K–8."

complex tasks will naturally draw upon securely held knowledge and skills. Many tasks in high school will demand flexible application of content knowledge first gained in grades 6–8 to solve complex problems. (See page 84 of the standards.)

- The following particular clusters of high school standards, which have wide relevance as prerequisites for a range of postsecondary college and career pathways:
 - Number and Quantity: Quantities:
 - Reason quantitatively and use units to solve problems.
 - Number and Quantity: The Real Number System:
 - Extend the properties of exponents to rational exponents.
 - Use properties of rational and irrational numbers.
 - Algebra: Seeing Structure in Expressions:
 - Interpret the structure of expressions.
 - Write expressions in equivalent forms to solve problems.
 - Algebra: Arithmetic with Polynomials and Rational Expressions:
 - Perform arithmetic operations on polynomials.
 - Algebra: Creating Equations:
 - Create equations that describe numbers or relationships.
 - Algebra: Reasoning with Equations and Inequalities:
 - Understand solving equations as a process of reasoning and explain the reasoning.
 - Solve equations and inequalities in one variable.
 - Represent and solve equations and inequalities graphically.
 - Functions: Interpreting Functions:
 - Understand the concept of a function and use function notation.
 - Analyze functions using different representations.
 - Interpret functions that arise in applications in terms of a context.
 - Functions: Building Functions:
 - Build a function that models a relationship between two quantities.
 - Geometry: Congruence:

- Prove geometric theorems.
- Statistics and Probability: Interpreting Categorical and Quantitative Data:
 - Summarize, represent and interpret data on a single count or measurement variable.

PARCC will be creating a portfolio of assessments for high school courses. Student scores from these assessments will contribute to an overall determination of college and career readiness valid for informing postsecondary educational decisions regarding placement into credit-bearing coursework. The overall determination will respond to evidence about college and career readiness by addressing mastery of fundamentals as well as the ability to solve complex problems by applying securely held knowledge and skills.

In the best view, the college- and career-ready line in the standards can be seen as a milestone, not a finish line; it is a line best crossed with velocity. In particular, students who wish to pursue science, technology, engineering or mathematics majors, or who wish to do college-level work in high school such as Advanced Placement or International Baccalaureate courses, must progress well beyond the initial threshold of college and career readiness as defined by the standards.

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