# ALIGNMENT BETWEEN THE CALIFORNIA COMMON CORE CONTENT STANDARDS FOR HIGHER MATHEMATICS (9-12) AND THE CALIFORNIA STATE UNIVERSITY ENTRY-LEVEL MATHEMATICS PLACEMENT TEST

by

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## Abstract

Six subject matter experts rated the alignment between the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University (CSU) Entry Level Mathematics (ELM) placement test using the Webb alignment analysis method and Marzano scale of cognitive demand, and found partial alignment in content, cognitive complexity, and breadth of knowledge. Content was aligned in Number and Quantity, Algebra, and Interpreting Functions. The ELM included too few items to align in Geometry or Statistics and Probability. Cognitive complexity was aligned at the lowest levels of cognitive demand. Eighty-four percent of the test items assessed the two lowest cognitive levels, requiring rote memorization/recall and comprehension. Fifteen percent of the items assessed higher order thinking skills requiring analysis. Zero items assessed the highest level of cognitive demand requiring knowledge utilization. Rather than assessing 3 years of rigorous high school math, including Algebra I, Algebra II, and Geometry as the ELM intended, reviewers found the majority of placement test items measured middle school math skills (Algebra I). The range of topics covered in the ELM was narrower than the range of topics addressed in the standards. The standards were distributed equitably in the assessment items.

A review of a 2010 ELM validity study showed that entering CSU students who scored below the ELM placement test cut-score, but enrolled in entry-level baccalaureate math courses without remediation were just as successful as students in the baccalaureate courses who scored above the cut score. The ELM failed to predict students who would succeed in the college-level math courses based on CSU success criteria, but was an effective predictor of highest performance (A and B grades).

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# CHAPTER 1: INTRODUCTION

Natalie is a goal-oriented high school student who aspires to attend a 4-year public university. She has taken the recommended pattern of college preparatory courses and has earned the grades needed for admission to the state university. Once admitted, however, she learns she must take a mathematics placement test to determine the highest course in which she can enroll that is most appropriate for her skill level. Unaware of the consequences and without an opportunity to refresh her skills, she takes the placement exam unprepared. Despite her good high school grades, her score on the college placement exam identifies her as not proficient in mathematics. She cannot enroll in a college-level mathematics course. Instead, the university requires her to enroll in and pass a remedial mathematics course for which she must pay, and will count toward financial aid, but will not earn credit toward her college degree. To her dismay, Natalie has discovered that what she learned in high school is different from what the university expects her to know to be ready for college-level courses (Conley, 2007a, 2007b).

Research is contradictory and inconclusive on what will happen to Natalie and the 1.7 million students in the U.S. who are assigned to remediation primarily in mathematics and/or English language arts (ELA) each year (Complete College America [CCA], 2012; Snyder & Dillow, 2011). Research is inconsistent regarding whether being placed into remediation facilitates or hinders degree completion (Attewell, Lavin, Domina, & Levey, 2006). Research also has overlooked the commonalities between students assigned to remediation and students who are not assigned to remediation but also are academically unprepared (Deil-Amen, 2011). A greater difference exists between academically prepared and unprepared students than exists between remedial and non-remedial students (Deil-Amen, 2011). Depending on a variety of student-related, institutional, and other factors:

- Academically unprepared students will struggle to persist and are at risk of not completing their degrees (Adelman, 2004; Attewell et al., 2006; Conley, 2007a, 2007b; Deil-Amen, 2011; Deil-Amen & Rosenbaum, 2002).
- Remedial students face institutional delays, and it will take them longer and cost more to earn the degree (Attewell et al., 2006; Bettinger & Long, 2004; Deil-Amen & Rosenbaum, 2002; CCA, 2012).
- Remedial students are more likely to withdraw or reverse-transfer to an open-access 2-year community college (Attewell et al., 2006; Bettinger & Long, 2004).
- Only 17-20% of remedial students persist to earn a baccalaureate degree (Conley, 2007a; National Center for Education Statistics [NCES], 2014).
- Thirty percent of remedial students do not show up for the first course or complete the course sequence (Attewell et al., 2006).
- Thirty percent who do complete remediation do not attempt the gateway college-level course in their degree program within two years after completing remediation (Bailey, 2009; Bailey, Jeong & Cho, 2010; CCA, 2012).
- Students who require fewest remedial courses are more likely to persist to degree completion than students who take multiple remedial courses, students who need remediation in writing as well as mathematics, and

students who are not proficient in reading (Adelman, 1998, 1999, 2004; Attewell et al., 2006; Deil-Amen & Rosenbaum, 2002; CCA, 2012).

- Seventy-five percent of community college students enrolled in remedial courses do not complete the sequence of remedial courses and drop out (Attewell et al., 2006; Boylan & Saxon, 1999).
- Remedial students might feel stigmatized and stereotyped by the remedial designation; fear seeking help; feel incompetent or fear that others perceive them as incompetent, negatively impacting their motivation to persist, invalidating their sense of belonging; and impeding their integration into the university, which are shown to contribute to student success (Astin, 1975, 1985; Deil-Amen & Rosenbaum, 2012; CCA, 2012; Kuh, 2005, 2007; Rendón, 1994; Tinto, 1987, 2006).
- Compared both with non-remedial students and remedial students who do not enroll in or complete the remedial course sequence, students who do complete remediation are more likely to persist and earn a degree (Attewell et al., 2006; Bettinger & Long, 2004).
- Remedial students who enroll in college-level courses while they are in remediation (co-requisite enrollment) are more likely to complete more courses successfully and earn more credits toward the degree than if they enroll in remedial or college-level-courses alone (CCA, 2012).

The role of remedial courses at baccalaureate-granting colleges and universities also is unsettled. Some 4-year institutions in a number of states no longer offer remedial coursework.

## Statement of the Problem

Colleges and universities are re-teaching during the first year of college what they expect entering students to have learned in high school (Achieve Inc., 2004, 2007; Adelman, 1999, 2006; Attewell et al., 2006). Despite having taken a college preparatory high school curriculum and earning a grade-point average that signals academic proficiency, a vast number of fully-qualified entering college students are not academically prepared to enroll in college-level courses as determined by a college placement test and are placed into remedial, non-degree credit, tuition-bearing courses (Attewell et al., 2006; Achieve Inc., 2007; California State University, Office of the Chancellor, Analytic Studies Division [CSU ASD], 2013; Callan, Finney, Kirst, Usdan, & Venezia, 2006; Conley, 2007b; CCA, 2012; Venezia & Kirst, 2005). Students' lack of readiness is attributed in great part to the lack of alignment between high school and higher education (Achieve Inc., 2004; Conley, 2007a, 2007b; Kirst, 2001; Kirst & Venezia, 2001; Smith & O'Day, 1991). Students learn in a disjointed educational system that imposes conflicting policies and academic standards, with one set of requirements to graduate high school, another set of conditions to be admitted to college and, once admitted, yet additional requirements to be placed into college-level courses (Kirst, 1998). The lack of coherence denies students not only the opportunity to learn, but also the opportunity to demonstrate that they possess the knowledge, skills, and abilities required to be successful in college-level courses, and derails many from persisting to degree completion (Anderson, 2002; Shelton & Brown, 2008).

### College-readiness

College-readiness, the most important factor contributing to bachelor's degree attainment, lacks a universally-accepted, agreed-upon definition. It is illdefined within and between educational sectors (ACT, 2009; Adelman, 1999; Callan et al., 2006; Conley, 2007b). Conley (2007b) described the traditional definition as the skills necessary to complete an entry-level general education course, without remediation, at a level of proficiency to progress to the next level at a postsecondary baccalaureate institution, or at a 2-year institution from which students can transfer to a baccalaureate institution. He expanded the definition beyond subject matter content knowledge to include a multi-faceted interacting set of factors encompassing four dimensions of knowledge, skills, attitude, and behavior. In order of significance, they are: key cognitive strategies; key content knowledge; academic behaviors; and contextual skills and awareness (Conley, 2007b). Conley's (2007b) comprehensive definition is illustrated more fully in the Definitions section of this study.

High school graduation tests assess the minimum skills students need to graduate high school and are not keyed to college readiness. College admissions tests define college readiness benchmarks by setting the minimum test score a student must achieve to have at least a 75% probability of earning at least a "C" in an entry-level college course (ACT, 2005; Conley, 2007b). Admissions tests, however, assess collective knowledge and the potential to perform well, and not subject-specific content knowledge. College placement tests assess students' readiness to take introductory college-level courses in specific subjects without remediation, typically ELA and/or mathematics.

Surveys of educators nationwide showed little concurrence between high school and higher education instructors' perceptions of college readiness (ACT, 2009). Vast differences in instructors' college readiness perceptions provide insight into causes underlying the problem of high college remediation and the need for secondary-postsecondary alignment (ACT, 2009). In its 2009 National

Curriculum Survey of 2,761 secondary teachers and 2,831 postsecondary instructors, ACT (2009) found deep divisions between high school and college instructors' perceptions of how well students are prepared to perform college-level work. Figure 1 is an infographic of ACT's 2009 National Curriculum Survey comparing high school and college instructors' perceptions of students' readiness to perform college-level work (Knewton, n.d.). The figure shows that while 91% of high school instructors perceived graduating high school seniors as well-prepared in their subject content areas, only 26% of college instructors believed so of incoming freshmen (ACT, 2009). Whereas 74% of college instructors perceived incoming students as not well prepared, only 9% of high school instructors had the same opinion (ACT, 2009).

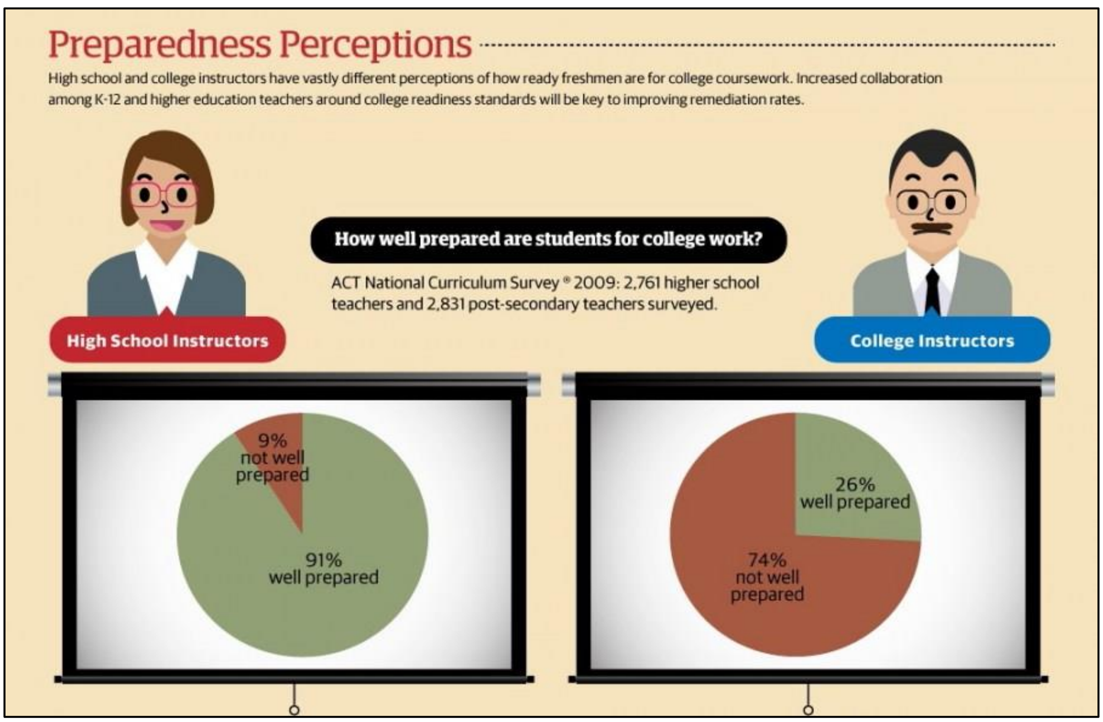


*Figure 1*. Infographic of ACT National Curriculum Survey (2009). Disparity in high school and higher education instructors' perceptions of students' college readiness. Reprinted from "Unprepared nation: College readiness today," by Knewton, n.d. Reprinted with permission.

The study further revealed similar vast differences in the groups' perceptions of how well state standards and high school graduation standards prepare students for college-level work. While 71% of high school instructors responded *well* or *very well*, only 20% of high education instructors did, and 55% of college instructors responded *poorly* or *very poorly* (ACT, 2009). High school instructors emphasized breadth over depth of subject matter content coverage while the reverse was true of college instructors, who emphasized more in-depth coverage of a narrower range of subject matter content (ACT, 2009). Figure 2 shows that while 61% of high school instructors believed that more than half of their students were ready for college-level math, only 31% of college instructors believed so of first-year students (ACT, 2009).

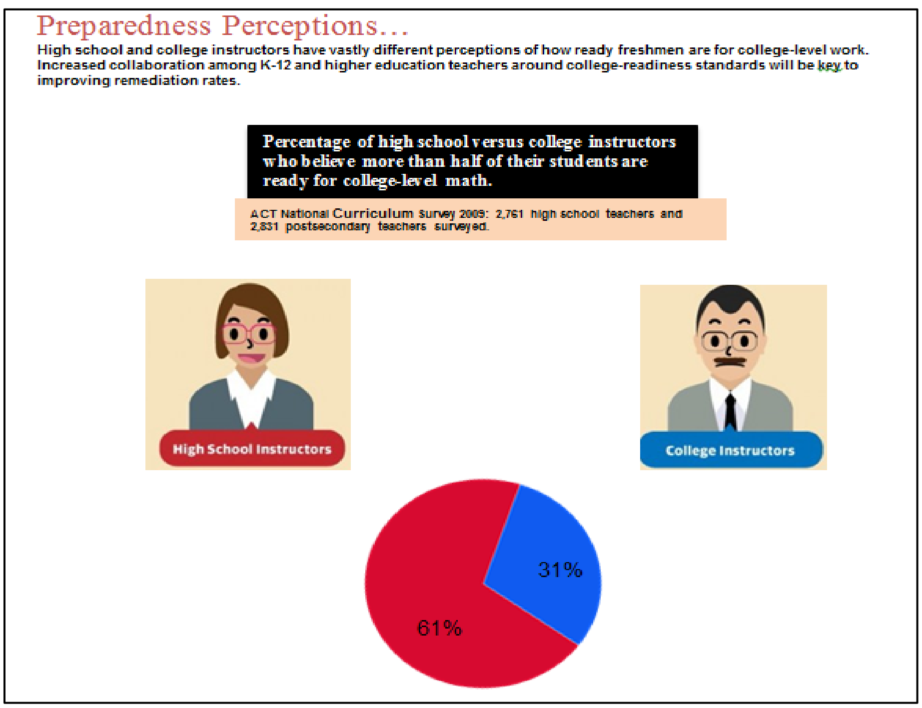


*Figure 2.* Infographic of ACT National Curriculum Survey (2009). Disparity in high school and higher education instructors' perceptions of students' readiness for college-level math. Adapted from "Unprepared nation: College readiness today," by Knewton, n.d. Reprinted with permission.

Most telling for mathematics is the striking disagreement between sectors about the most important math content and skills students should learn. Table 1 and Table 2 reveal that high school and higher education instructors are at polar opposites about the math skills important for students to learn to be college-ready. Only one of the skills listed in College Algebra instructors' top 10 skills also is in high school Algebra II instructors' top 10 list, while eight of the college instructors' top 10 rank 26 or below for high school instructors (ACT, 2009). The converse also was true, with only one of the Algebra II instructors' top 10 skills listed as such for College Algebra's instructors. High school instructors focused on more advanced topics while higher education instructors emphasized fundamental math concepts as necessary for success in College Algebra (ACT, 2009).

Table 1

*Rank-Ordered List of Mathematics Topics by Postsecondary Instructor Importance*

| Post-secondary Rank | High School Rank | Content and Skills |
|---|---|---|
| 1 | 27 | Perform addition, multiplication, subtraction, and division on signed rational numbers |
| 2 | 39 | Solve routine first-degree equations |
| 3 | 45 | Add and subtract simple algebraic expressions |
| 4 | 61 | Locate points in the coordinate plane |
| 5 | 47 | Solve routine two- or three-step arithmetic problems |
| 5 | 52 | Evaluate algebraic expressions by substituting integers for unknown quantities |
| 5 | 19 | Solve linear equations and inequalities in one variable |
| 8 | 65 | Exhibit knowledge of elementary number concepts (e.g., rounding, decimal ordering, pattern identification, absolute value, primes, and greatest common factor) |
| 9 | 16 | Recall basic facts, definitions, formulas, and algebraic expressions as needed to solve a problem |
| 9 | 3 | Apply rules of exponents |
| 9 | 90 | Comprehend the concept of length on the number line |

*Source*: (ACT, 2009, p. 19.)

Table 2

*Rank-Ordered List of Mathematics Topics by High School Teacher Importance*

| Post-secondary Rank | High School Rank | Content and Skills |
|---|---|---|
| 28 | 1 | Solve quadratic equations |
| 54 | 2 | Evaluate quadratic functions based on function notation |
| 9 | 3 | Apply rules of exponents |
| 20 | 4 | Factor quadratics |
| 45 | 5 | Understand the concept of function |
| 19 | 6 | Add, subtract, and multiply polynomials |
| 46 | 7 | Evaluate linear functions based on function notation |
| 12 | 8 | Use mathematical symbols correctly |
| 65 | 9 | Find solutions to systems of linear equations |
| 59 | 10 | Find domain, range, and inverses of functions |

*Source*: (ACT, 2009, p. 19).

With such an extreme divide in instructors' importance perception, it is not surprising that students receive conflicting messages and are confused about what is important for them to learn to be college-ready, that they underprepare, and are placed into remediation. What students learn is dictated by what they are taught (Anderson, 2002). If they are not taught, they are denied the opportunity to learn (Anderson, 2002). The disjuncture undermines and even derails students' aspirations and efforts to earn a college degree (Bailey, 2009; Callan et al., 2006; Kirst, 1998). Deil-Amen and Rosenbaum (2002) described the systemic misalignment as a cruel hoax perpetuated on unaware high school students who unknowingly underprepare for college (Attewell et al., 2006).

## Remediation

Remediation has become a defining feature of higher education and pervades all institution types. Remedial students are numerically in the mainstream (Deil-Amen, 2011; Herzog, 2005). NCES data show that 76% of all 2- and 4-year degree-granting Title IV colleges and universities offer remedial courses (Parsad, Lewis, & Greene, 2003). Private 4-year institutions are not exempt, as 59% of private 4-year institutions join the 80% of public 4-year institutions and 98% of 2-year public colleges that offered at least one remedial course in reading, writing, or mathematics (Parsad et al., 2003). Nearly half of all undergraduates require at least one remedial course (Hodara, 2013; Scott-Clayton & Rodriguez, 2012), with 52%-75% of 2-year college students and 20% of 4-year college students enrolled in remedial courses (CCA, 2012; Deil-Amen, 2011). Remediation disproportionately affects students of color and low-income students, as remediation is highest in open- and broad-access institutions, and 80% of students of color and low income students enroll at open- and broad-access institutions *even when they are eligible for admission to more selective institutions* (CCA, 2012; Kirst, Antonio & Bueschel, 2004). Table 3 shows the remediation rate by ethnicity and income, by institution type. Remediation is higher for all groups at 2-year institutions, higher for students of color at all institutions, and high for all low-income students (CCA, 2012).

Table 3

*Percentage Remediation by Institution, Race/Ethnicity, and Income*

| | Race/Ethnicity | | | | Low Income |
|---|---|---|---|---|---|
| Institution Type | African American | Hispanic | White | Other | |
| 2-Year | 67.7% | 58.3% | 46.8% | 48.9% | 64.7% |
| 4-Year | 39.1% | 20.6% | 13.6% | 16.9% | 31.9% |

Adapted from CCA, 2012.

The magnitude, prevalence, and pervasiveness of remediation are symptomatic of and illuminate the lack of articulation between the secondary and postsecondary systems evinced in a growing body of research literature (Adelman, 1998, 1999, 2006; Attewell et al., 2006; Callan et al., 2006; Conley, 2003; Kirst, 1998; Merisotis & Phipps, 2000; Parsad et al., 2003; Venezia & Kirst, 2005).

Adelman's (1999) seminal longitudinal high school transcript study of two high school cohorts indicated that weak high school academic preparation, as opposed to remediation itself, lowers the likelihood of college degree attainment, and that high school academic rigor, or the level of cognitive complexity or demand of expected learning, is the strongest predictor of degree completion. Kirst (1998) attributed weak academic preparation to educational misalignment.

**Which students are enrolled in remedial courses?** Attewell et al. (2006) asserted that the commonly-held perspective that remediation results from poorly functioning high schools, and the portrayal of remedial students as academically weak, low-income students of color from inner-city high schools who take less rigorous courses, are stereotypes unsupported by empirical findings, and is a perspective that oversimplifies, underserves, and truncates the issue. Adelman's (1999) National Educational Longitudinal Study (NELS:88) high school transcript data evinced that remediation is not the sole province of economically disadvantaged students of color, as the national sample of students who took remedial courses included:

- 24% of students from the highest socioeconomic status;
- 10% of students who scored in the highest quartile on 12th grade math/reading assessment;
- 25% of students who scored in the second highest quartile on 12th grade math/reading assessment;
- 14% of students enrolled in the most rigorous high school curriculum;
- 32% of students in the second quartile of most demanding high school curriculum;
- 40% were from rural high schools;
- 37% were from suburban high schools; and

- 52% were from urban high schools.

Conversely, students who were not enrolled in remediation included:

- 32% of students in the lowest quartile of the 12th grade math/reading assessment; and
- 42% of students enrolled in the least demanding high school curriculum (Adelman, 1998; Attewell et al., 2006).

These data indicate only a partial overlap of remediation and low academic skills and show high variability and arbitrariness in remedial assignment (Attewell et al., 2006).

Attewell et al. (2006) pointed out that while the data also bear out that African American students were substantially more likely to enroll in remediation courses than White students with the same socioeconomic status, academic preparation, and skills (61% and 35%, respectively), it was unclear whether African American students were *required*, *advised*, or *chose* to enroll in the courses (Adelman, 2006). Although the issue is outside of the scope of this study, it merits further research.

**Definition and designation of remedial student status.** The definition of remedial status varies by institution and even within institutional systems. The designation traditionally is a binary, college-ready/remedial decision based on the result of students' placement test performance in mathematics or ELA (reading and writing) (Deil-Amen, 2011; Scott-Clayton, 2012). Students who score above an established minimum cut-score are deemed academically prepared to pass college-level courses, and those who score below the minimum threshold are designated as requiring remediation (Deil-Amen, 2011; Scott-Clayton, 2012). How and which students are placed into remedial courses varies considerably across institutions, systems, districts, sectors, and states. Placement policies range from mandatory to self-directed, voluntary, as a function of academic advising, and/or other subjective criteria, each of which has a differential impact on successful remediation (Adelman, 1999; Boylan, Bliss, & Bonham, 1997; Deil-Amen, 2011; Levin & Calcagno, 2008; Perin, 2006; Roueche & Snow, 1977). Faculty overrides of mandatory placement policies are not uncommon, as faculty opinions of students' appropriate placement influence placement decisions. Some students are non-compliant in that they disregard the finding and simply do not enroll in remedial courses, and enroll instead in the college-level course (Deil-Amen, 2011). Although not officially designated as remedial, meriting further research are students who enroll in, drop, or fail college-level courses, (particularly in math and science), and must re-take the course, reverse-transferring to a community college to complete the course and re-enrolling either at the native or a different 4-year institution after successful course completion. These students blur the remedial/non-remedial 2-/4-year institution designations but are a part of the remedial student population (Deil-Amen, 2011).

**College Placement Assessments**

The purpose of the college placement assessments is to determine whether students have mastered the skills required to be placed into the college-level introductory course of a program of study. Students do not "pass" or "fail" placement tests. The placement test score is used to predict the probability of a student's success in a credit-bearing, college-level course. "Success" is defined differently across institutions. Based on the probability of the student's success, students who score above an established cut score are placed into the college-level course and students who score below the cut score are placed into or a remedial course as a treatment to build the student's skills to successfully complete the college-level course (Scott-Clayton, 2012).

Venezia, Kirst, and Antonio (2003) suggested that to improve the transition from high school to college, the relationship between college placement exams and high school standards should be examined. Placement exams are prolific across the country, and neither are standardized nor transferrable across institutions (Kirst, 1998). The Southern Regional Education Board counted a mélange of 75 different college and university placement exams in use in some 125 combinations (Kirst, 1998). Even within institutional systems that use a common instrument and cut score, placement policies, practices, and decisions vary substantially from campus to campus (Harmon, 2011). A student who, based on placement test results, would be placed into remediation on one campus could be placed into college-level courses at another or varying levels of a remedial course sequence at still other campuses. Some institutions use assessments developed by commercial enterprises such as the ACT's COMPASS and the College Board's ACCUPLACER exams. Others are developed by an institution's department faculty. Still others are developed jointly by commercial enterprises and institutional faculty.

**Validity of college placement assessments.** Predictive validity as an element of placement validity is based on the assumption that students should not be placed into courses they are apt to fail; that students who fail are more likely to succeed if they first are placed in a lower-level course; and that high placement test scorers would not benefit, or would minimally benefit, from first being placed in a lower-level course (Bridgeman & Wendler, 1989). A growing body of research on the validity of college placement exams indicates that students who were placed in remedial courses could have performed successfully in college-level courses (also known as *gatekeeper* courses) and that placement test cut scores, the establishment of which require judgement and variability, are arbitrary and inconsistent across institutions (Armstrong, 2000; Bailey et al., 2010; Belfield & Crosta, 2012; Calcagno & Long, 2008; Conley, 2010; Educational Testing Service [ETS], 2010; Merisotis & Phipps, 2000; Roska, Jenkins, Jaggars, Zeidenberg, & Cho, 2009; Scott-Clayton, 2012; Shelton & Brown, 2008). In a study of more than 24,000 community college students, Roska et al. found little difference in the remedial and non-remedial students' passage rate in gatekeeper courses. While nearly 75% of students who took gatekeeper courses passed them, there was no marked difference in the passing rates of student who previously had taken remedial coursework and students who did not (Roska et al., 2009). Placement test scores were related to whether students *took* (had access to) a gatekeeper course. They were not strongly related to whether students *passed* the course (Roska et al., 2009). Students recommended for remediation who instead enrolled directly in the gatekeeper course were just as successful as students recommended for remediation who did take the remedial course prior to enrolling in the gatekeeper course, and were equally successful at meeting other desired student learning outcomes (accumulating credits, earning degrees, and transferring to a 4-year institutions) (Roska et al., 2009).

Scott-Clayton (2012) analyzed placement data for more than 42,000 first-time community college students in a large, urban community college system to evaluate the predictive validity of the test scores on student success in the gatekeeper college-level courses. Using analysis of variation, placement accuracy and error rates, the study found severe misplacement errors, with high rates of over- and under-placement (Scott-Clayton, 2012). Consistent with previous placement assessment research, the study found:

- a weak correlation between placement test scores and future course outcomes;

- placement tests to be more predictive for mathematics than for English; and
- placement tests to be better predictors of students more likely to succeed than for those more likely to fail (Scott-Clayton, 2012).

Comparing placement test scores alone to other preparedness indicators, the research further found that:

- high school grades alone were better predictors of success and yielded lower severe error rates;
- adding placement test scores to high school grades added little improvement; and
- a predictive measure that combined test score, high school background, and student motivation substantially reduced the severe error rate (Scott-Clayton, 2012).

In examinations of placement test validity, Belfield and Crosta (2012) and Scott-Clayton (2012) discovered severe error rates in placement tests as predictors of student performance in college-level courses. Similarly, Calcagno and Long's (2008) discontinuity regression study showed that the similarities between students scoring above and below the cut score were so great that their distinctions as remedial and non-remedial were arbitrary.

## Purpose of the Study

Scott-Clayton (2012) pointed out that the common practice in the exploration of the high college remediation rate has been to focus on high schools and, for example, academic rigor, student course-taking patterns, and state standards. Rarely have placement exams been the subject of rigorous, empirical research (Scott-Clayton, 2012). The purpose of this study was to determine the extent to which the California Common Core Content Standards for Higher

Mathematics (9-12) were aligned with the California State University system's Entry-Level Mathematics placement assessment.

**Research Questions**

The overarching research question was: To what extent will successful completion of mathematics courses as prescribed by the California Common Core content standards for higher mathematics lead to mastery of the skills required for college-level math placement as determined by the California State University Entry-Level Mathematics placement test? The following specific research questions guided the study:

1. To what extent are the California Common Core Content Standards for Higher Mathematics (9-12) aligned with the California State University Entry-Level Mathematics placement test?

2. What cognitive demands are emphasized in the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University Entry-Level Mathematics placement test, respectively?

3. What is the alignment between the breadth of knowledge of the standards and the assessment?

The ELM is the *de facto* standard for college-level mathematics in the CSU. It is against this standard of college readiness that the current study measured the CA CCSSM (9-12). The study used a mixed-methods research approach and utilized subject-matter experts to analyze and code standards and assessment items, using math-specific language that identified topics and cognitive demand for each item. The analysis revealed any content areas that differed and those with high and low degrees of consistency. The study built upon and extended the curriculum alignment research of Webb (1997, 1999, 2002), Brown and Conley (2007), Brown and Niemi (2007), Shelton and Brown (2008), and

Conley et al. (2011). The research design adapted Webb's (1997, 1999, 2002) widely accepted and well-regarded standards-to-assessment alignment methodology and used the Webb Alignment Tool (WAT), an online software program developed for the alignment analysis methodology (Webb, Alt, Ely, & Vesperman, 2005). A purposive sample of mathematics and educational assessment experts at the secondary and postsecondary levels analyzed each item in the CA CCSSM (9-12) and the ELM against four criteria: 1) categorical concurrence; 2) depth of knowledge correspondence; 3) range of knowledge consistency; and 4) balance of representation. Data were displayed using standard methods. Post-analysis open-ended interviews with the math experts were used to validate the quantitative data collected.

## Background

### National Crisis and Educational Reform

The 1983 landmark report *A Nation at Risk: The Imperative for Educational Reform* infamously described the quality of U.S. education as "a rising tide of mediocrity" that was attributable to low academic standards and the failure of the American school system (National Commission on Excellence in Education [NCEE], 1983, p. 5). Citing declining test scores and last place showings in international comparisons of academic achievement, the report warned that downward spiraling student performance placed the nation's economic, scientific, and military preeminence at risk of being subordinated by educationally superior competing countries (NCEE, 1983). The fuller statement provided the broader context for understanding the report's alarm, asserting the national risk resulting from declining educational achievement, and its resulting call for educational reform:

> Our Nation is at risk… the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur--others are matching and surpassing our educational attainments.
>
> If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war. As it stands, we have allowed this to happen to ourselves. We have even squandered the gains in student achievement made in the wake of the Sputnik challenge. Moreover, we have dismantled essential support systems which helped make those gains possible. We have, in effect, been committing an act of unthinking, unilateral educational disarmament. (NCEE, 1983, p. 5)

Although extensively criticized for high rhetoric and low evidence of its claims of a failing educational system, *A Nation at Risk* thrust the nation solidly into a new era of standards-based reform and triggered a testing tidal wave (Berliner & Biddle, 1995). To the report's claims, Clark Kerr, President Emeritus of the University of California, responded: "Seldom in the course of policymaking in the U.S. have so many firm convictions held by so many been based on so little convincing proof" (Berliner & Biddle, 1995).

Three of the report's five key recommendations to achieve academic excellence were in curriculum content, teacher education, and school accountability (NCEE, 1983). The report recommended that high schools establish for all students an updated minimum core curriculum for post-high school success, and that high school and higher education establish "more rigorous and measurable standards" (NCEE, 1983, p. 24). Four years of high school English, three years each of mathematics, science, and social studies, and one-half year of computer science became the new basic core curriculum (NCEE, 1983). Specifically regarding math, it recommended that graduating students should be equipped to understand geometry, algebra, elementary probability and statistics, and application of mathematics to daily life, and that a demanding math curriculum be developed for non-college bound students (NCEE, 1983). Among its most significant outcomes, the report shifted the focus of measuring school educational effectiveness from teacher and resource input to student outcomes.

**Declining Global Economic Competitiveness**

Citing reports of the nation's declining ranking in international comparisons of student achievement and educational attainment, President Barak Obama warned that "…the nations that out-teach us today will out-compete us tomorrow" and established an ambitious goal within the first six months of his first administration that "…by 2020, America will once again have the highest proportion of college graduates in the world" (Obama, 2009a, para. 66). Emphasizing the connection between college completion, educational attainment, and global competitiveness, he stated later that year:

> At a time when our children are competing with kids in China and India, the best job qualification you can have is a college degree or advanced training. If you do have that kind of education, then you're well prepared for the future -- because half of the fastest growing jobs in America require a Bachelor's degree or more. And if you don't have a college degree, you're more than twice as likely to be unemployed as somebody who does. So the stakes could not be higher…America cannot lead in the 21st century unless we have the best educated, most competitive workforce in the world. (Obama, 2009b, para. 2 and 4)

Educational attainment is a critical factor in determining economic well-being and progress (Barro & Lee, 2001). As a proxy for human capital (available labor force skills), greater educational attainment is an indicator of more skilled and productive workers; higher production of goods and services; and increased use of advanced technology (Barro & Lee, 2001). Among American adults age 25-64, 42% have earned an associate's degree or higher, which positions the U.S. fifth out of 36 nations composing the Organization for Economic Cooperation and Development (OECD) and Group of Twenty Finance Ministers and Central Bank Governors (G20). The U.S. ranking trails the Russian Federation (53%), Canada (51%), Israel (46%), and Japan (46%) (OECD, 2013). Among 25-34-year-olds, however, the U.S. ranking has dropped substantially over the last two decades from first in 1990 to 13th in 2011 (OECD, 2013) as other OECD countries' level of educational attainment is rising at a rapid rate while the U.S. rate has stagnated. Figure 3 is a slope graph showing the steep upward trajectory in the increase of 25-34-year-old tertiary degree holders in other countries from 2000 to 2011, outpacing the U.S. (OECD, 2013). Without intervention and greater increases, the U.S. will sink to 18th by 2020.

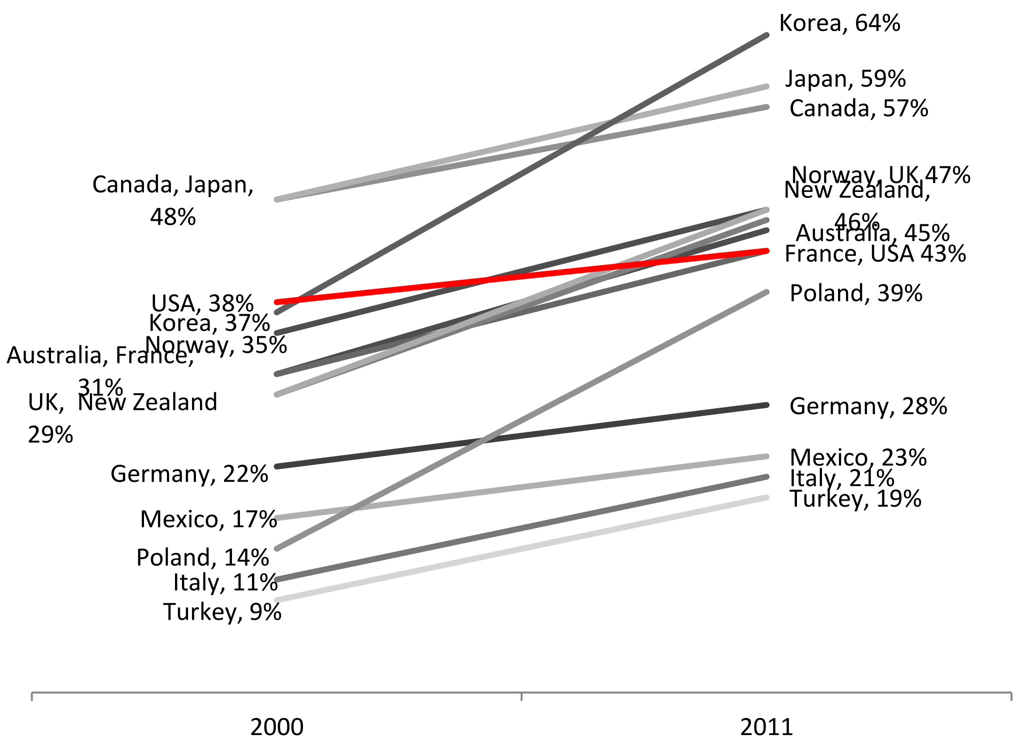


*Figure 3*. Percentage of 25-34-year-olds in a sample of OECD countries who have attained a postsecondary degree, 2000-2011. Author's compilation from data accessed from OECD (2013), Table A1.4a.

In a knowledge-based global economy, a good education is a pre-requisite for, and no longer simply a pathway to, opportunity and "the countries that out-teach us today will out-compete us tomorrow" (Obama, 2009a, para 63). President Obama characterized the combination of high school and college drop-out rates as part of a "prescription for economic decline" (Obama, 2009a, para 63). Each high school dropout costs the nation $260,000 in lost lifetime earnings compared with a high school graduate (Tyler & Lofstrom, 2009). High school dropouts in the 2012 cohort alone will cost the nation an estimated $263 billion in unrealized lifetime earnings (Alliance for Excellent Education, 2014). With more than one million students dropping out of high school each year, an anticipated 13 million will drop out over the next decade, with a cumulative loss of unrealized income estimated at $3 trillion (Tyler & Lofstrom, 2009).

At the postsecondary level, students typically depart between the first and second year (Herzog, 2005). Students who take remedial courses in their first year of college are less than half as likely to earn a degree within 150% of normal time as non-remedial students (Jenkins & Boswell, 2002; Parsad et al., 2003). Lower degree completion decreases employment opportunities, lowers lifetime salary earnings, and negatively impacts economic vitality and global competitiveness (Johnson & Sengupta, 2009; U.S. Department of Labor, 2014). The estimated losses for one year for one cohort of college dropouts is $3.8 billion in lost income, $566 million in lost federal income taxes; and $164 million in lost state income taxes (Schnelder & Yin, 2011). Over the work life for just the one cohort, the losses are estimated at $158 billion in income; $2 billion in federal income taxes; and $7 billion in state income tax payments (Schnelder & Yin, 2011).

On the other hand, baccalaureate degree holders earn almost three times the weekly salary of a high school dropout and almost twice that of a high school graduate, and are substantially less likely to be unemployed (U.S. Department of Labor, 2014). Figure 4 depicts 2013 median weekly earnings and unemployment by level of educational attainment. As the figure shows, higher levels of education equate with higher incomes and lower rates of employment.

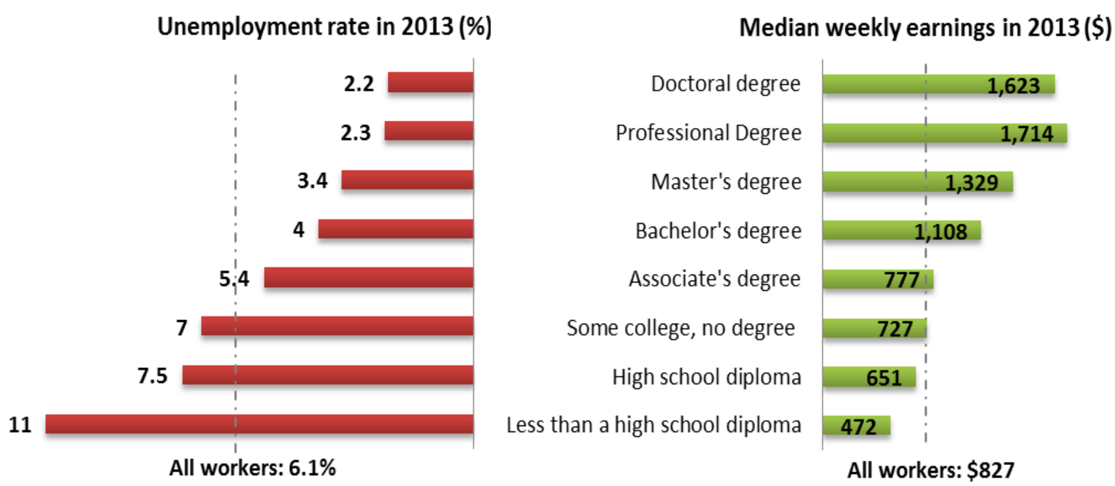


*Figure 4.* Earnings and unemployment rates by educational attainment, 2013. Source: U.S. Department of Labor (2014) Bureau of Labor Statistics.

The importance of educational attainment on economic well-being is perhaps most starkly illustrated by data on poverty. Poverty is reduced substantially as the level of education increases. Despite having a median household income 15% higher than the national median income, California's poverty rate is higher than the national rate and varies widely by county (Wimer, Mattingly, Levin, Danielson, & Bohn, 2013). Figure 5 shows, by level of education, the U.S. Census Bureau's official poverty measure (OPM) and the California poverty measure (CPM), a new metric developed by the Public Policy Institute of California (PPIC) and the Stanford Center on Poverty and Inequality. The measures differ in that the OPM, developed 50 years ago, uses a food-based poverty threshold, does not account for California's high cost of living and regional differences thereof, and does not consider the poverty-reducing effect of safety net government programs available to low-income households, whereas the CPM addresses these issues. Figure 5 shows the sharp decline in poverty rates with higher levels of education. The poverty rate for persons without a high school diploma is almost six times higher (53.9%) than for persons with a college degree (9.8%). The poverty rate even among persons with some college (21.7%) is twice the rate of those with a college degree.

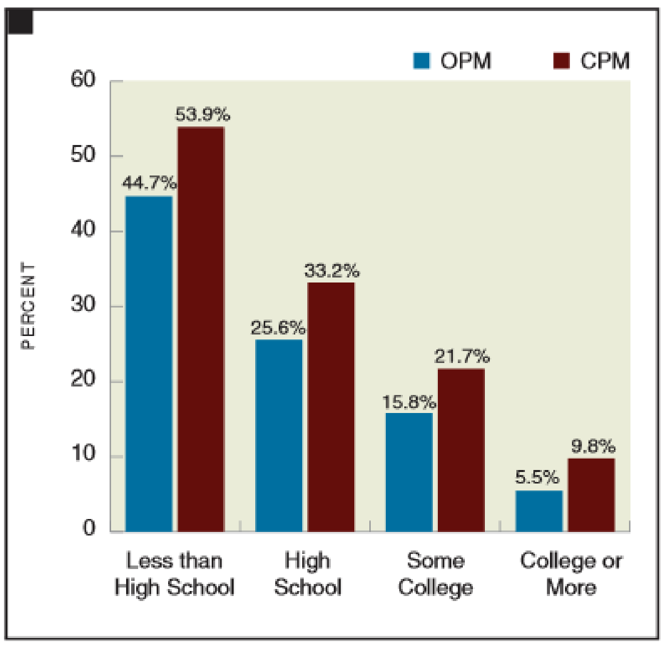


*Figure 5*. Comparison of the overall poverty measure and the California poverty measure by level of educational attainment. Adapted from Wimer et al., 2013, *A Portrait of Poverty Within California Counties and Demographic Groups*, p. 6.

These data evidence the impact of degree completion on economic well-being and have substantial implications for California and the college-readiness rates of high school students discussed earlier in this chapter. Given the magnitude and consequences of the high school and college drop-out rate, ensuring a continuum of competitive education from cradle to career to elevate the level of educational attainment beyond the high school diploma is a national priority for the Obama administration. Now just five years before the 2020 target, low college degree completion rates continue to challenge President Obama's 21st Century Global Leadership Goal.

**The Shortage of Degreed Workers**

Carnevale, Smith, and Strohl (2013) asserted that the U.S. has been under-producing college graduates for more than thirty years and at the current rate of college degree completion the labor market will face a shortage of 5 million degreed workers by 2020. Analyzing job growth and educational requirements, they forecasted a 2020 U.S. labor force of 164 million people, with the economy creating 24 million new and 31 million replacement jobs due to retirements and other labor force exits between 2010- 2020. More than one-third (36%) of the 55 million job openings will require at least a bachelor's degree. While 30% of jobs will require some college (18%) or an associate's degree (12%), the percentage in these categories has been relatively flat over the decades (see Figure 6).

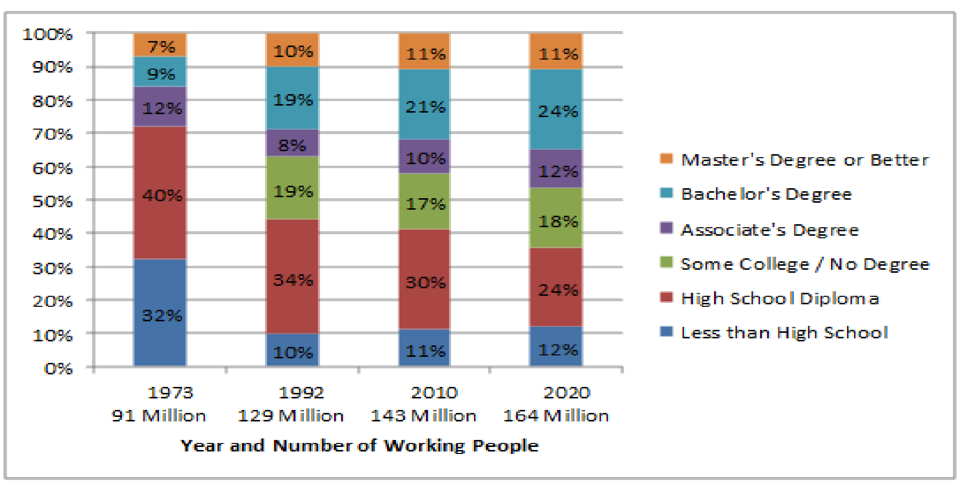


*Figure 6.* U.S. labor market and postsecdonary education 1973-2020. Carnevale et al., 2013, *Recovery: Job Growth and Education Requirements Through 2020*, p. 15.

The greatest growth has been for jobs requiring a bachelor's degree, whereas jobs that require only a high school diploma and less have declined sharply over the decades (Carnevale et al., 2013).

The highest demand for postsecondary degrees will be in the education, government, and healthcare industries concentrated in managerial, office, and education occupations (see Table 4). More than 80% of the jobs in education, healthcare, and professional and business services will require a postsecondary degree (Carnevale et al., 2013). In 2010, 95% of the STEM jobs, 93% of the healthcare professional and technical jobs, 90% of the jobs in education, and 88% of the community services and arts job openings required at least a postsecondary education (Carnevale et al., 2013).

Table 4

*Occupations by Educational Attainment, 2010*

| | Educational attainment (thousands) | | | Postsecondary education only | |
|---|---|---|---|---|---|
| Occupation | Professional degree | PhD | Total | Total jobs ('000) | All jobs (%) |
| Sales & office support | 150 | 50 | 37,660 | 22,600 | 60 |
| Blue collar | 30 | 10 | 28,400 | 8,740 | 31 |
| Food & personal services | 60 | 20 | 23,220 | 9,330 | 40 |
| Managerial & professional office | 1,060 | 280 | 19,980 | 15,570 | 78 |
| Education | 200 | 410 | 8,160 | 7,350 | 90 |
| Healthcare professional & technical | 890 | 260 | 6,480 | 6,040 | 93 |
| STEM | 80 | 290 | 6,050 | 5,750 | 95 |
| Community services & arts | 110 | 70 | 6,290 | 5,510 | 88 |
| Healthcare support | 30 | 10 | 3,660 | 2,160 | 59 |
| Social science | 40 | 190 | 700 | 700 | 100 |
| Total jobs | 2,650 | 1,590 | 140,600 | 83,750 | |
| Percent of total jobs | 2 | 1 | 100 | 59 | |

*Note*: Numbers differ slightly due to rounding. Source: Carnevale et al. (2013).

Three of the four fastest-growing occupational clusters are in the sciences (see Table 5). Professional and technical occupations in healthcare will grow the fastest with a 31% increase by 2020, followed by healthcare support services (albeit with low wage growth), community services and the arts, and STEM, each with 26% growth (Carnevale et al., 2013). As occupations and job openings in the science clusters increase, so will the importance that students arrive at college-ready, able to succeed in college-level mathematics.

Table 5

*Largest and Fastest-growing Industries, 2010-2020*

| | | | | | Changes in employment 2010-2020 | | Rank | |
|---|---|---|---|---|---|---|---|---|
| Occupation | 2010 Total jobs (‘000) | Rank | 2020 Total jobs (‘000) | Rank | Increase in jobs (‘000) | Rate of growth (% change) | Largest growth | Fastest growth |
| Healthcare profession & technical | 6,480 | 6 | 8,490 | 6 | 2,010 | 31 | 5 | 1 |
| Healthcare support | 3,660 | 9 | 4,610 | 9 | 950 | 26 | 9 | 2 |
| Community services & arts | 6,290 | 7 | 7,920 | 7 | 1,630 | 26 | 7 | 3 |
| STEM | 6,050 | 8 | 7,600 | 8 | 1,550 | 26 | 8 | 4 |
| Education | 8,160 | 5 | 10,120 | 5 | 1,960 | 24 | 6 | 5 |
| Managerial & professional office | 19,980 | 4 | 24,740 | 4 | 4,760 | 24 | 1 | 6 |
| Social science | 700 | 10 | 830 | 10 | 130 | 19 | 10 | 7 |
| Food & personal services | 23,220 | 3 | 27,380 | 3 | 4,160 | 18 | 3 | 8 |
| Sales & office support | 37,660 | 1 | 42,130 | 1 | 4,470 | 12 | 2 | 9 |
| Blue collar | 28,400 | 2 | 30,750 | 2 | 2,350 | 8 | 4 | 10 |
| Total jobs and rate of growth (% change) | 140,600 | | 164,590 | | 23,990 | 17 | | |

*Source*: Carnevale et al., 2013, p. 13.

**California's skills gap.** The PPIC projects that by 2025, 41% of the state's job openings will require at least a bachelor's degree and only 35% of working age adults will have earned one, equating to a shortage of 1 million workers with a bachelor's degree (Johnson & Sengupta, 2009). Similarly, 36% of available jobs are projected to require some college education less than a bachelor's degree, and only 28% of working age adults will have acquired such training, bringing the projected shortfall of workers with a postsecondary degree education to more than 2 million (Johnson et al., 2009). The state's demographic trends that negatively impact the number of degreed workers include the retirement of the well-educated baby boomer generation exiting the workforce and the rising college enrollment of first-generation, academically under-prepared students, who historically have low, but improving, degree completion rates (Johnson et al., 2009). California's economy requires substantial improvement in educational outcomes to meet the need for a highly educated workforce. To maintain global economic competitiveness, the U.S. must develop more college graduates.

## Academic Standards

Academic standards provide guidance for the taught curriculum and are intended to shift instruction from an emphasis on concrete facts, rote memorization, and lower-order thinking skills to higher-order critical thinking, problem solving, and abstract reasoning skills that facilitate transferrable learning (Darling-Hammond, Herman, Pellegrino, Abedi, Aber, Baker, et al., 2013; Porter, 1994). The shift in instruction is intended to foster a shift in student achievement, as students learn best what they have the opportunity to learn, and cannot learn what they are not taught (Porter, 1994).

Reeves (2002) described academic standards as the fairest way to assess student performance. Standards are the alternative to comparing students to each other as manifested by the bell curve and normal distribution, referenced by an average "C" grade (Reeves, 2002). Norm-referenced evaluations that compare student performance to a hypothetical average student are inaccurate in that, while they purport to assess proficiency, they only evaluate performance in comparison to an average (Reeves, 2002). Comparison to an average does not denote proficiency or the cognitive ability to perform higher level work. For example, a student who as met a proficiency requirement still can be designated as below average when compared to students who performed at a higher level.

In response to the *A Nation at Risk* report, task forces were formed by governors, state and local educational officers, legislators, and business leaders in nearly all of the states to study and recommend changes to their respective educational systems. Its focus on test scores gave attention to the achievement gap of socio-economically disadvantaged students. Most states implemented reform strategies. High school graduation and college admission requirements were increased (e.g., increasing course credits in math and science) (Lee, 1997). State-mandated, top-down educational reforms of the early 1980s focused on inputs and expanding the existing system (more of the same), but did little to change instruction, concepts of teaching and learning, or engage teachers in the reform process, and perpetuated policy fragmentation (Smith & O'Day, 1991).

Minimal learning gains of the first wave prompted a second wave of bottom-up reform in the mid-to-late1980s that was initiated, designed, and developed by teachers and principals who advocated restructuring the process of education to improve student learning outcomes, with the school as the unit of change (Smith & O'Day, 1991). Educators developed internally-driven school-based initiatives that considered the teaching and learning needs of each school to effect changes in classroom instruction and practice. Site-based management, parental choice, and teacher preparation, certification, professionalism, and collaboration, for example, emanated from this reform movement (Lee, 1997; Smith & O'Day, 1991). While some school improvements occurred, the school-by-school approach was ineffective to generalize change on a large scale or to effect the widespread reconceptualization of teacher-centric pedagogy and fact-based knowledge necessary to develop students' higher order thinking and problem-solving skills (Smith & O'Day, 1991).

The 2002 passage of the *No Child Left Behind Act* was deemed the most comprehensive reform of the ESEA since its authorization in 1965 (No Child Left Behind [NCLB], 2003; Smith & O'Day, 1991; Superfine, 2005). NCLB's greatly expanded role of the federal government in education nearly doomed it to failure; however, the terrorist attacks of 9/11 elevated its priority on the public agenda, and bipartisan passage was accomplished in large part because education was re-framed as a matter of national security (DeBray, 2006; Superfine, 2005). NCLB mandated states to demonstrate annually that their standards and assessments met five specific alignment criteria: content focus; articulation across grades and ages; equity and fairness; pedagogical implications; and system applicability (Webb, 2007). The federal legislation incentivized closing the achievement gap, rewarding success and sanctioning failure (DeBray, 2006). Critics of the legislation state that it incentivized schools to "dumb down" tests that raise passage rates for compliance (DeBray, 2006). While NCLB specified assessment criteria, it did not specify a threshold for acceptable alignment or required degree of alignment, nor an alignment methodology. Thus, by the early 2000s, every state had developed and adopted its own learning standards that specify what students in grades 3-8 and high school should be able to do. Every state also had its own definition of proficiency. This lack of standardization and comparability among the states was one reason states moved to develop the Common Core State Standards in 2009.

**Misaligned standards**. Academic standards define the *intended* curriculum; that is, the subject matter content teachers are expected to teach and students are expected to know and be able to do as a result of instruction (*what* is to be taught, not *how* it is to be taught). However, "[n]o state created educational standards and assessments for the express purpose of increasing college enrollment or success" (Conley, 2003, p. 9). That state academic standards and college expectations are not aligned is well-researched and documented (Kirst, 1998; Kirst & Venezia, 2004; Shelton & Brown, 2008) but it is not common knowledge among high school students and parents, who reasonably assume that the educational system is a seamless progression from one segment to the next, and that learning is sequential and cumulative.

Further confounding students, high school teachers, counselors, and parents regarding alignment of college placement are high school and college courses with the same or similar names but which differ in their topic coverage and emphasis (Achieve Inc., 2007). As shown in Table 6, the first two introductory college math courses are considered remedial. Algebra I, the math course required for high school graduation, is considered remedial at the college level. Algebra II, which is not required for high school graduation, also is considered remedial in the equivalent introductory college math course (Achieve Inc., 2007). Mathematics beyond the minimum high school graduation level is necessary to be prepared for college-level mathematics (Achieve Inc., 2007).

High school exit examinations typically are administered in the $10^{th}$ grade and test what students have learned through the second year of high school (Conley, 2007b). Thus, students can graduate high school with a $10^{th}$ grade level

Table 6

*Mathematics Course Titles in High School and College and Proficiency Level*

| **High School** | **=** | **College** | **Proficiency Level** |
|---|---|---|---|
| Algebra I (Arithmetic and Elementary Algebra) | = | Elementary Algebra | R (2 levels) |
| Algebra II | = | Intermediate Algebra | R (1 level) |
| Pre-calculus | = | College Algebra | CL |
| Calculus | = | Calculus | CL |

Source: Achieve (2007). [R = Remedial; CL = College-Level]

of knowledge, which is inadequate to be admitted to college and placed in college-level courses (Conley, 2007b). College admissions examinations such as the SAT and ACT test general knowledge and not specific content knowledge. College placement tests are subject matter standards of what colleges and universities expect students to know and be able to do to perform first-year college-level work (Porter, Polikoff, & Smithson, 2009). The disjuncture causes students to underprepare for college-level work and to be found wanting academically.

**Common Core State Standards**

To close the gap between high school standards instruction and higher education expectations for college success, states adopted the Common Core State Standards (ACT, 2009; Common Core State Standards Initiative [CCSSI], n.d.). Common Core represents a new wave of educational reform that calls for participation of all sectors as opposed to reform initiatives of previous decades that occurred in isolated sectors. Adopted by the majority of states in August 2010 in order to qualify for federal Race to the Top funding (California Department of Education [CDE], 2013a), the standards are intended to raise academic rigor for K-12 ELA and math, and to define clearly and standardize across states and grade levels, the core knowledge and skills expected for college- and career-ready students.

The Common Core State Standards Initiative is a voluntary and state-led collaboration of the National Association of Governors and Council of Chief State

School Officers (National Governors Association [NGA] Center for Best Practices, Council of Chief State School Officers [CCSSO]). Although national in scope, it is not a federal initiative. The internationally-benchmarked shared standards have been adopted by 44 states, four territories, the District of Columbia, and the Department of Defense Education Activity (CSSI, n.d.). Alaska, Texas, Nebraska, Indiana, Virginia, and Puerto Rico have not adopted the standards, and Minnesota adopted only the ELA standards (CSSI, n.d.). Each state adopts the standards in their entirety and may add up to 15% in additional standards specific to the state.  The California State Board of Education adopted the standards in August 2010, modified them in January 2013, implemented them in the 2013-14 academic year, and piloted assessments in Spring 2014 (CDE, 2013a).

**Common Core practice standards**.  The mathematics standards are divided into two categories: practice and content standards. The eight Standards for Mathematical Practice standards are the same for each grade level and reflect the “habits of mind” that all students should develop to build the knowledge, skills, and expertise (CDE, 2013b):

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.

California has one additional math practice standard, MP 3.1: Students build proofs by induction and proofs by contradiction (CDE, 2013b).

**Common Core content standards**. The Standards for Mathematical Content vary by grade level. Standards are organized by grade for K-5 in the following six strands: Counting and Cardinality; Operations and Algebraic Thinking; Number and Operations in Base Ten; Fractions; Measurement and Data; and Geometry (CDE, 2013b). Progression for grades 6-8 are as follows: Ratios and Proportional Relationships; Expression and Equations; The Number System; Statistics and Probability; and Geometry. Higher level (high school) math standards are not arranged by grade level. Instead, as Table 7 shows, they are arranged by conceptual categories that cross traditional course and grade-level boundaries: Number and Quantity; Algebra; Functions; Geometry; and Statistics and Probability (CDE, 2013b).

Table 7

*Mathematical Content Domains (K-8) and Conceptual Categories (Higher Mathematics)*

| Grade | K | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Higher Mathematics Conceptual Categories | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Domains K-8 | Counting & Cardinality (CC) | | | | | | Ratios & Proportional Relationships (RP) | | Functions (F) | Functions (F) | Modeling (*) |
| | Operations and Algebraic Thinking (OA)<br>Number and Operations in Base Ten (NBT) | | | | | | Expression and Equations (EE) | | | Algebra (A) | |
| | | | | Number and Operations – Fractions (NF) | | | The Number System (NS) | | | Number & Quantity (N) | |
| | Measurement and Data (MD) | | | | | | Statistics and Probability (SP) | | | Statistics & Probability (S) | |
| | Geometry (G) | | | | | | Geometry (G) | | | Geometry (G) | |

*Source*: CDE, 2015. Retrieved from http://www.cde.ca.gov/ci/ma/cf/documents/mathfwoverview.pdf

Appendix A provides a link to the California Common Core Content Standards for Higher Mathematics (9-12) by conceptual category. California added several standards statements, reflected in bold type and with the designation "CA" following the standard.

## Context of the Study

As California is the most populous state in the union, it follows that its public K-16 enrollment also is the largest, with more than 4.3 million students enrolled in grades K-8; 1.9 million students enrolled in grades 9-12; and 2.5 million students enrolled in higher education in Fall 2013 (NCES, 2014; National Student Clearinghouse Research Center, 2013). California's public secondary and postsecondary education systems are the context for this study of the alignment between the academic standards and placement assessments governing the transition from high school to higher education. More than 6 million students enrolled in more than 1,000 school districts are governed by more than 1,000 different elected school boards in the state (CDE, 2014).

### California's College Enrollment and Completion Rates

While California awards more bachelor's degrees than any other state in the union, the state's college-going rate lags behind the national average and shows a downward trend. According to the California Postsecondary Education Commission [CPEC] (2011), from 1985 to 2009, the state's college-going rate (public high school graduates enrolling in public higher education) declined from 48.1% to 40.6%, with 7.2% of public high school graduates entering the University of California (UC); 10.5% enrolled in the CSU; and 22.9% enrolled in the community college systems. The data show similar enrollment declines by ethnicity. The statewide college-going rate by ethnicity for 2009 was: All students: -- 40.6%; Asian PI -- 61.6%; Black -- 36.0%; Filipino -- 49.4%; Latino -- 38.7%; Native American -- 29.2%; White -- 36.4% (CPEC, 2011). Figure 7 is a map by county of 2010 California high school graduates who completed the A-G requirements to be eligible for admission to the UC or the California State University. In the majority of counties, less than one-third of high school graduates complete the pattern of courses required for UC or CSU admission.

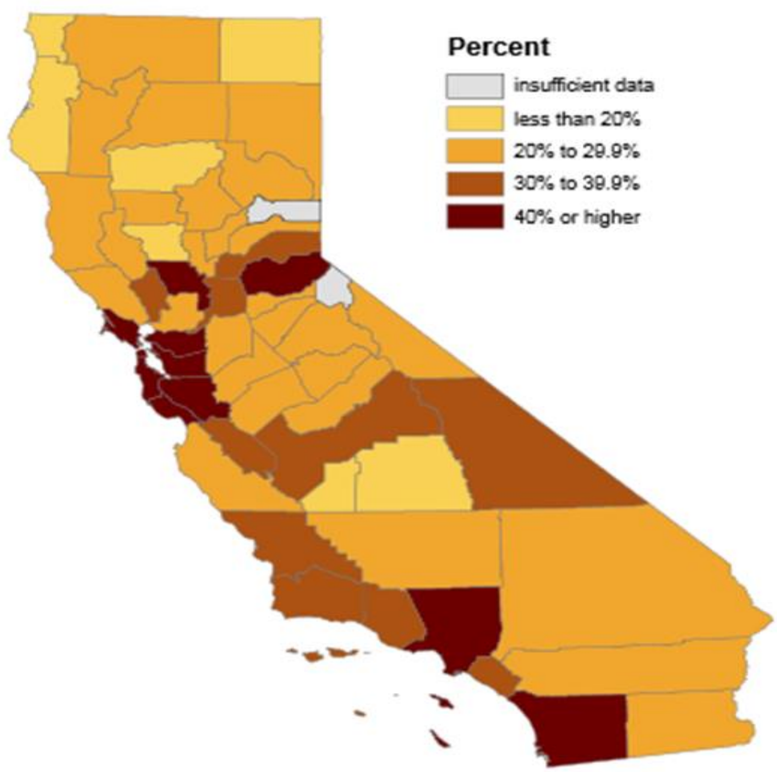


*Figure 7.* Percentage of students by California county who have taken the A-G course pattern for admission to the UC or CSU. Reprinted from Johnson, H. (2012). *Data Set: Maps of College Enrollment Rates in California's Counties,* (Map 1). Based on data from the CDE and CPEC. Copyright 2012 by the PPIC. Reprinted with permission.

**California's 1997 mathematics content standards**. California is among the few states regarded as pioneers in establishing highly centralized rigorous academic standards coordinated with other policies and programs (Smith & O'Day, 1991). The California State Board of Education's 1997 Mathematics Content Standards for California Schools reflect its core value that mathematics proficiency is essential to equip students to be globally competitive, informed citizens. The rigorous standards reflect the core beliefs that math skills are not innate; rather, the skills are the result of giving students the opportunity to learn and attendant support and encouragement, and students' persistence and effort (CDE, 2006). The study of Algebra I by the eighth grade for all students was a primary goal of the mathematics framework (CDE, 2006). In 2000, state legislators codified legislation making Algebra I a requirement for graduation (CDE, 2006; California Education Code Section 51224.5(b), 2000).

Eligibility for admission to a California 4-year public university requires successful completion of coursework beyond the state-mandated requirements for high school graduation (CDE, 2013b). This succinct statement epitomizes the multiple and confounding sets of educational policies faced by students transitioning from high school to higher education in California. While the California Education Code establishes minimum requirements students must meet to graduate from high school, California public universities have established a more rigorous set of minimum requirements for admission, called "A-G" requirements, to prepare students for college-level study (CDE, 2013b; California Education Code 51225.3, 1985). Table 8 shows the state-mandated minimum subject area requirements for high school graduation, and requirements for admission to the University of California (UC) and the CSU system.

Table 8

*Subject Area State Minimum Requirements for High School Graduation and A-G Requirements for UC & CSU Admission*

| Subject Area | High School (EC 51225.3) | UC Admission | CSU Admission |
|---|---|---|---|
| a: History/Social Science | 3 yrs., incl. U.S. hx. and geog.; world hx., culture, and geog., 1 sem. Am. Govt. & civics; 1 sem. Economics | 2 yrs. hx/soc. sci., incl. 1 yr. U.S. hx or ½ yr. U.S. hx & ½ yr. civics or Am. Govt., 1 yr. world hx., cultures, & geog. | 2 yrs., incl. 1 yr U.S. hx or U.S. hx. & govt. & 1 yr. approved soc. sci. |
| b: English | 3 yrs. | 4 yrs. approved courses | 4 yrs. approved courses |
| c: Mathematics | 2 years, incl. algebra I (EC 51224.5) | 3 yrs., incl. algebra, geometry, and intermed. algebra | 3 yrs., incl. algebra, intermed. algebra, & geo. |
| d: Laboratory Science | 2 yrs., incl. bio. & phys. sci. | 2 yrs. w/lab, bio., chem., or physics | 2 yrs., incl. 1 yr. bio. and 1 yr. phys. sci. w/lab |
| e: Foreign Language | 1 yr. FL, VAPA or CTE* | 2 yrs., same language | 2 yrs., same language |
| f: Visual & Performing Arts | 1 yr. VAPA, FL or CTE* | 1 yr. dance, drama/theatre, music, or visual art | 1 yr. dance, music, drama/theatre, visual art |
| g: College Prep. Elective | N/A | 1 yr. | 1 yr. |
| Physical Education | 2 yrs. | N/A | N/A |
| TOTAL | 13 | 15 (7 in last 2 years of h.s.) | 15 |

Source: CDE, 2014b. Graduation Requirements. Retrieved from http://www.cde.ca.gov/ci/gs/hs/hsgrtable.asp
*VAPA is visual and performing arts; FL is foreign language, and CTE is career technical education

The A-G requirements include 15 courses in seven subject areas which students must pass with a grade “C” or better. The courses are designed to prepare students for advanced study. Important differences include not only the number of courses required, but also the additional year of English and mathematics, including intermediate algebra and geometry (CDE, 2013b).

***Common Core in comparison with California standards.*** Among the emerging research on the Common Core, The Fordham Institute compared existing state ELA and math standards with the Common Core ELA and math standards (Carmichael, Martino, Porter-Magee, & Wilson, 2010). The review found the Common Core standards to be clearer and more rigorous than the math standards in 39 states, the ELA standards in seven states, both the ELA and math standards in 33 states, and too close to call in 11 states (Carmichael et al., 2010). The review found California’s standards – that is, the *intended* curriculum -- to be exemplary and “clearly superior” to the Common Core in ELA and too close to call in math, giving both a rare “A” grade. Of California’s *enacted* curriculum; that is, what actually is taught in the classroom, the report stated that its “lackluster follow-through has left excellent standards without traction” (Carmichael et al., 2010, p. 4). As importantly, it determined that, at the high school level, Common Core math standards are less well organized, and that mathematical coherence suffers compared with California’s exemplary writing and organization of its mathematics standards (Carmichael et al., 2010).

**California’s public higher education system**. Long esteemed as a model system, California’s tri-partite system of public higher education was established in 1960 by the California Master Plan for Higher Education (the *Donahoe Act*) to reduce competition for students among the sectors, foster collaboration, and provide access to higher education to all who could benefit from it (Bracco &

Callan, 2002; CDE, 1960). Each sector has statutorily differentiated roles, missions, admissions standards, governance, and funding sources.

The 10-campus doctoral-granting University of California system enrolls almost 240,000 students and is the primary academic research and public service institution. Under its selective admissions standard, the UC accepts students in the top one-eighth (12.5%) of the high school graduating class.

The broad-access 23-campus California State University system admits students in the top one-third (33.3%) of high school graduates; educates through the master's level and the educational doctorate; and has the primary responsibility for teacher education.

The California Community College system has 112 campuses in 72 districts, each with its own governing board as well as a system-wide coordinating board. The community college enrolls 2.1 million students through an open admissions policy under which any high school graduate (or equivalent) who may benefit from education may enroll in academic coursework that leads to an associate's degree or transfers to a 4-year institution; vocational coursework that leads to certification; or courses for personal enrichment. As Figure 8 shows, of all students in public higher education in California, 66% are enrolled in community colleges, 13% are enrolled in the CSU, and 6% are enrolled in the UC (Johnson, 2015).

***Fragmented governance***. Compared with the governance and policy structures of other highly developed nations, the American tradition of decentralized, fragmented governance system and local control is unique, as most highly performing nations have in common a coherent, centralized, integrated policy system (Smith & O'Day, 1991). The Master Plan did not establish a higher education coordinating body with regulatory *authority* (Bracco & Callan, 2002);

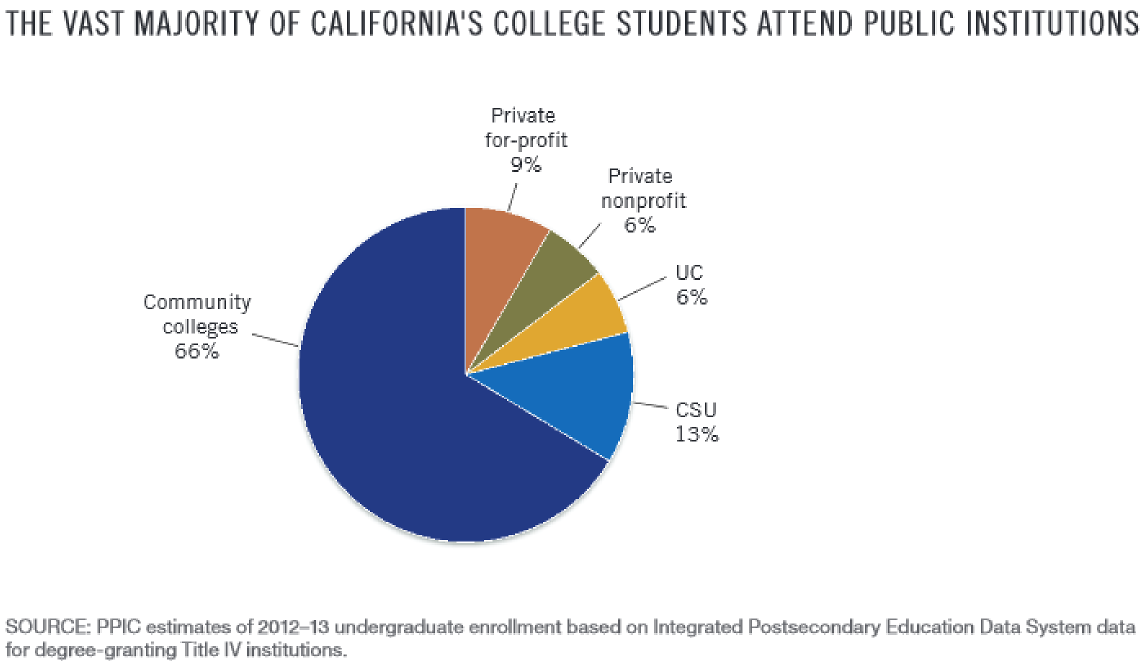


*Figure 8.* The percentages of California college students enrolled at public and private colleges and universities. Johnson, J. (2015). California's Future: Higher Education, p. 2.

thus, there is no authoritative incentive for the sectors to coordinate policies (Kirst, 2001). The UC is governed by a 26-member Board of Regents. A 25-member Board of Trustees governs the CSU, and a 17-memebr Board of Governors governs the CCC.

**The California State University system**. The CSU is the largest 4–year public higher education system in the world. Fall 2013 enrollment was 446,530 (CSU Office of the Chancellor, 2014a). Roughly 75% of CSU students are enrolled full-time; 25% are enrolled part-time and the mean age of undergraduates is 23. Ethnic breakdown is as follows in Table 9.

The mean grade point average of CSU students entering Fall 2013 was 3.33 (CSU ASD, 2013), indicating grades of As and Bs. Despite having taken the college preparatory "A-G" pattern of courses required for admission to the CSU, 44% of regularly admitted first-year CSU students were placed into remedial

Table 9

*CSU Systemwide Undergraduate Enrollment by Ethnic Group, Percent of Total, 2004 & 2013*

| Ethnicity | 2004 | 2013 |
| --- | --- | --- |
| African American | 5.8 | 4.6 |
| American Indian | 0.7 | 0.4 |
| Asian | 13.2 | 15.8 |
| Filipino | 4.8 | 1.3 |
| Mexican American | 16.1 | 26.8 |
| Other Latino | 6.1 | 8.1 |
| Pacific Islander | 0.6 | 0.4 |
| White | 36.3 | 28.1 |
| 2 or More Races | --- | 4.5 |
| Unknown | --- | 5.6 |
| Non-Resident Alien | --- | 4.4 |

Source: Adapted from CSU Analytic Studies, Statistical Reports, CSU Enrollment by Ethnic Group, Fall 2013 Profile, Table 1.

courses (CSU ASD, 2013). Figure 9 shows CSU remediation placement from 1997-2012 (CSU ASD, 2012a). Although the percentage dropped from 63% in Fall 1997, it is far short of the CSU Board of Trustees' ambitious goal of no more than 10% remediation and at least 90% proficiency of first-time students by 2007 (CSU Board of Trustees, 1997).

In Fall 2013, 29.1% were placed into remedial math, a decline from 54.0% in Fall 1997 (CSU ASD, 2013). Disaggregated CSU student demographic data also show that the need for math remediation among students of color also is declining, but remain higher than for their non-white counterparts. Figure 10 presents the percentage of regularly-admitted freshmen who needed math

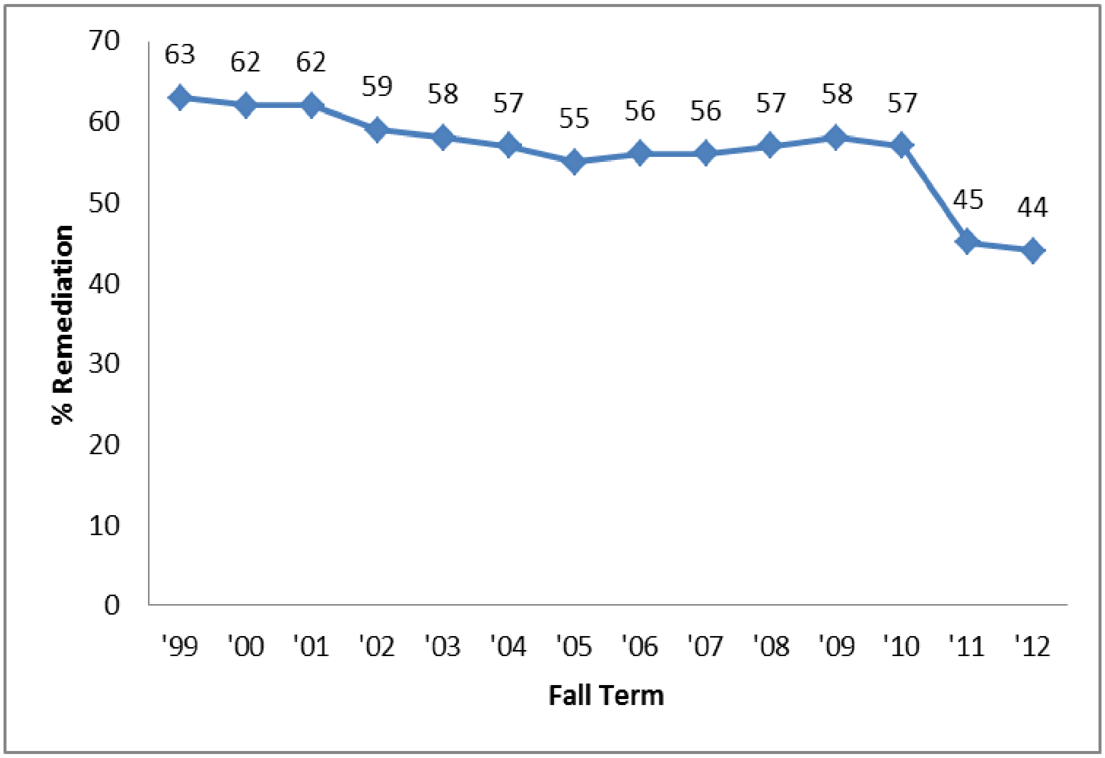


*Figure 9.* Percentage of regularly-admitted first-time CSU freshmen requiring remediation Fall 1999-2012. Author's compilation from CSU ASD data from CSU Freshman Proficiency and Remediation Combined, 1999-2012. Retrieved from http://www.asd.calstate.edu/performance/proficiency.shtml.

remediation, by ethnicity, from Fall 2009 to Fall 2013. The math remediation rate for entering African American students remains at above 50% and hovers around 40% for students of Mexican-American and other Latino descent (CSU ASD, 2013). By gender, 35.7% of first-year females compared to 20.3% of first-year males required mathematics remediation. The mean high school grade point average of first-year students needing math remediation was 3.17 while that for the freshman cohort at large was 3.36 (CSU ASD, 2013).

A similar need exists for ELA remediation, as shown in Figure 11. The mean GPA of regularly-admitted first-time freshmen who need remediation is 3.20 and the mean GPA of freshmen in general is 3.36.

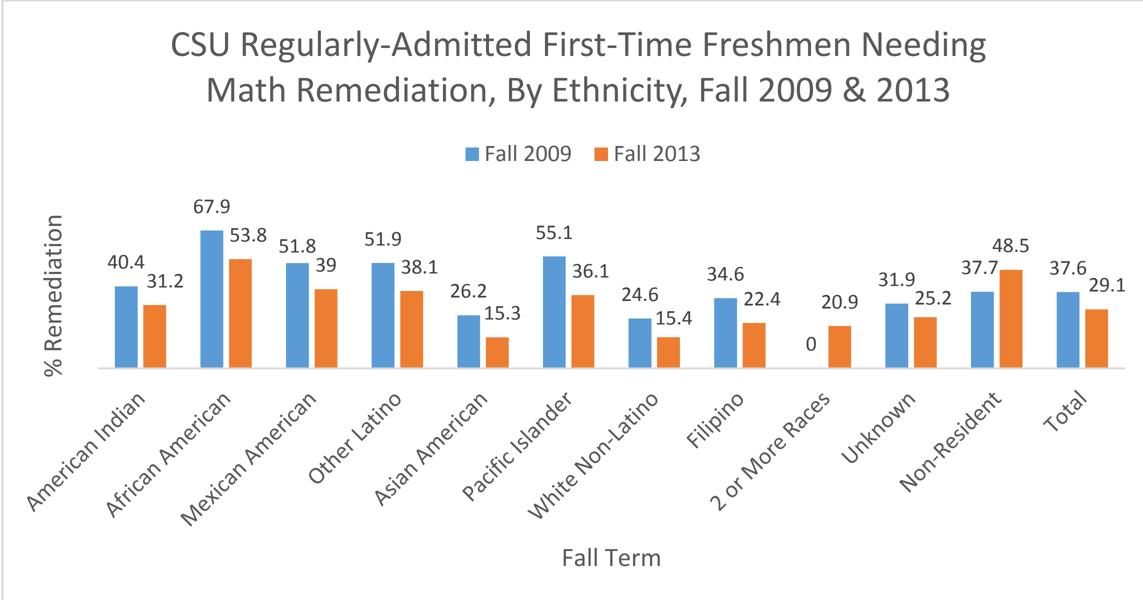


*Figure 10*. CSU regularly admitted first-time freshmen needing math remediation, by ethnicity, Fall 2009 and Fall 2013. Source: Compiled from CSU ASD data from CSU Freshman Remediation Rates Systemwide, 2009-2013. Retrieved from http://www.asd.calstate.edu/performance/proficiency.shtml

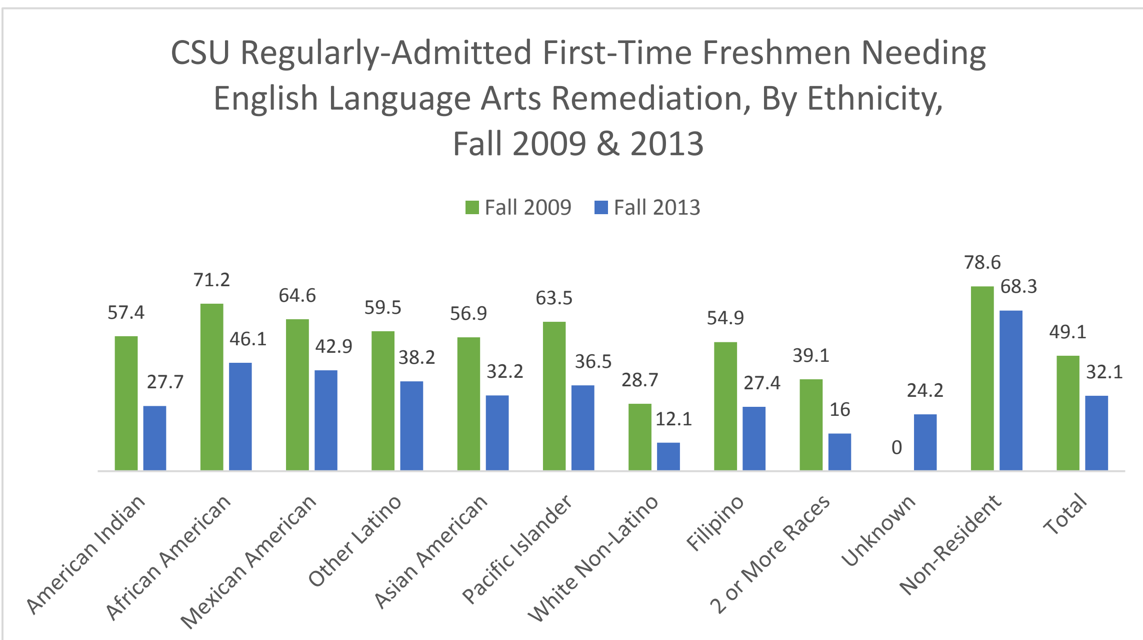


*Figure 11*. CSU regularly admitted first-time freshmen needing ELA remediation, by ethnicity, Fall 2009 and Fall 2013. Author's compilation from data from CSU Freshman Remediation Rates Systemwide, 2009-2013. Retrieved from http://www.asd.calstate.edu/performance/proficiency.shtml

The CSU mandates both completion of remediation coursework prior to enrollment in college-level courses (Executive Order [EO] 665) (Munitz, 1997), and compliance within one year of remedial placement on penalty of disenrollment (EO 1048) (Reed, 2010). (Interestingly, EO 1048 *misquotes* EO 665 as requiring achievement of proficiency before the end of the first year of enrollment, when it actually requires that "students who do not demonstrate the requisite competence in mathematics are *placed* in appropriate remedial developmental programs/activities during the first term of enrollment *and each subsequent term until such time as they demonstrate competence*" (Munitz, 1997, p. 3. Emphasis added.)). Under EO 665, campuses are "encouraged to establish and enforce limits on remedial/developmental activity" (p. 3), but does not itself impose a 1-year limit on remediation (Munitz, 1997). Remediation policies are implemented differentially on the various CSU campuses and little research has been conducted regarding the effectiveness of remediation on student learning outcomes in the CSU system (Harmon, 2011). Of the 54,478 regularly-admitted first time students admitted to the CSU in Fall 2012, 44% or 24,691students required remediation; 85% were proficient one year later; 11% did not complete remediation and were dis-enrolled; and 4% did not complete remediation but were allowed to re-enroll (CSU ASD, 2012b).

**The CSU Early Assessment Program (EAP)**. To help students graduate high school ready to take entry-level college courses, and to align its placement assessment with high school ELA and math standards, the CSU developed the Early Assessment Program in 2004. A collaborative effort among the California State Board of Education, the CDE, and the CSU, the EAP includes three components: an early college-readiness assessment; a full-year college-preparatory $12^{th}$ grade Expository Reading and Writing Course developed jointly by high school teachers and CSU faculty; and a professional development program for 11th and 12th grade ELA and math teachers (CSU Office of the Chancellor, n.d.).

The early assessment consisted of 15 questions in reading, writing, and math incorporated as a supplement to the state-mandated California Standardized Test (CST) administered to every California eleventh grader in public high school as part of the Standardized Testing and Reporting (STAR) assessment system. The EAP was not mandated. Students answered the questions on a voluntary basis as part of the Augmented CST (CSU Office of the Chancellor, n.d.). Based on EAP results, students were assessed as “ready,” “conditionally ready,” or “not ready” to perform college-level work. Students determined as ready for college were exempt from taking the CSU’s Entry-Level Mathematics placement test and/or the English Placement Test. Students assessed as not ready or conditionally ready could take course(s) in their senior year of high school to would improve their skills and overcome identified academic deficiency(ies) prior to enrolling in their first college course.

As of 2013, EAP results were accepted by more than 70 California community colleges (Torlakson, White, & Harris, 2013). Effective January 2014, California Assembly Bill 484 established a new K-12 assessment system, the California Measurement of Academic Performance and Progress (CalMAPP), replacing the STAR program and ending CST testing. The new Smarter Balanced Assessment Consortium test, piloted in Spring 2014, incorporates the EAP’s college readiness indicators.

**The CSU English Placement Test (EPT)**. The CSU English Placement Test assesses entering students’ reading and writing proficiency for placement in appropriate entry-level college courses (CSU Office of the Chancellor, 2014b).

All entering first-year students must complete the EPT unless exempted.by achieving a qualifying score on any of the following assessments:

- 500 or higher on the critical reading section of the College Board SAT Reasoning Test
- 22 or higher on the American College Testing (ACT) English Test
- 3 or higher on either the Language and Composition or Composition and Literature examination of the College Board Scholastic Advanced Placement Program
- "Exempt" or "Ready for college-level English courses" on the CSU EAP
- “Conditionally ready for college-level English courses” on the CSU EAP, with successful completion of the Expository Reading and Writing Course (ERWC), AP English, IB English or other approved English course
    - Completion with a grade of C or higher, and transfer to CSU, of the credits for a college course that satisfies the CSU General Education requirement in English Composition (CSU Office of the Chancellor, 2014b).

**The CSU Entry-Level Mathematics (ELM) placement exam**. The CSU ELM placement test was developed collaboratively by ETS, CSU mathematics faculty, and faculty in related disciplines. The target population is incoming undergraduate students who have been admitted to the CSU but who have not shown proficiency in math in their senior year of high school. The placement test is designed to measure the mathematics skill level of entering first-year CSU students for the purpose of placing them into the General Education quantitative reasoning course in which they are most likely to be successful (C- or better). All non-exempt students must take the ELM in order to enroll for classes, whether their major is quantitative or non-quantitative. The exam assesses skills in math content typically covered in three years of college preparatory high school math courses.

The ELM is a 90-min timed test with 50 multiple choice questions (45 are scored and five are field-tested for future use), 35% of which cover Numbers and Data; 35% Algebra; and 30% Geometry. The ELM is administered during eight different time spans throughout the year and may be taken at any CSU campus, but may be taken only once. The cut score is 50 on a scale of 0 to 80. Students who score at least 50 may enroll in a college-level mathematics course. Students who score below 50 are placed into remedial math. As of summer 2012, students who score below 50 are required to enroll in the CSU's Early Start program during the summer prior to the freshman year. Early Start is designed to strengthen math skills so that students are ready to take credit-bearing courses at the start of the freshman year. Students may be exempted from taking the ELM by demonstrating proficiency by achieving minimum scores on the following assessments:

- 550 or above on the math reasoning portion of the SAT Reasoning Test
- 550 or above on an SAT mathematics test, Levels 1 or 2;
- at least 23 on the ACT mathematics test;
- at least a 3 on the Advanced Placement Calculus or Statistics tests;
- "Ready for College-level Math" on the CSU EAP test taken in the $11^{th}$ grade
- "Conditionally Ready for College-level Math" on the CSU EAP test, conditioned on the passage of a $12^{th}$ grade math course, Algebra II or higher, grade C or higher (CSU Office of the Chancellor, 2014b).

***The validity of the CSU ELM placement test***. The ELM is required by the CSU Board of Trustees to undergo "ongoing validity" (ETS, 2010, p. 3). Despite the high stakes of the consequences of using the ELM to predict student success or failure in credit-bearing courses, the thousands of students impacted each year, and the CSU Board of Trustees' mandate for validity testing of the CSU's proficiency exams, research on the validity of the ELM is sparse, and the scant studies undertaken by the CSU generally are available only to system personnel.

Scott-Clayton's (2012) and Belfield and Crosta's (2012) findings of weak correlations between placement test scores and future course grades are consistent with those concealed in a 2010 unpublished validity study of the CSU's Entry-Level Mathematics placement exam conducted by ETS. The study was obtained through a Public Records Act request (Harmon, 2011). The unpublished statistical report studied CSU first-year math students (N = 35,652) to determine the ELM's effectiveness in predicting students' success in math courses, as defined by their final course grades. Students in the lowest level of baccalaureate math courses and the highest level of pre-baccalaureate (remedial) math courses in Fall 2008 participated in the study. Table 10 shows the performance of students in college mathematics courses by grades earned and ELM score. Passing grades were defined as "A," "B," "C," or "Credit." Final course grades were utilized to assign students to "Pass/Fail." Failing grades were defined as "D," "F," "No Credit," "Pass No Credit," and "Unsatisfactory." "Audit," "Withdraw," "Incomplete," and "Repeat" were defined as "No Grade."

Table 10 shows that in the baccalaureate courses, students who placed below the ELM's cut score were *just as successful* in earning a grade of "Pass" as those who placed at or above the cut score (ETS, 2010). By definition, "Pass" is a final course grade of A, B, or C, had a letter grade been assigned. The distribution of those grades is unknown. There was no meaningful difference between the two groups. In fact, the percentage of baccalaureate-level students

Table 10

*Course Performance for CSU Students Taking College Mathematics Courses*

| Course Description | N | % A | % B | % C | % Credit | % Pass | % Fail | % No Grade |
|---|---|---|---|---|---|---|---|---|
| Baccalaureate | | | | | | | | |
| ELM ≥ 50 | 4,414 | 20.2 | 29.2 | 26.1 | 1.5 | 77.0 | 19.9 | 3.1 |
| ELM ≤ 50 | 2,852 | 5.0 | 10.6 | 10.9 | 51.3 | 77.8 | 20.8 | 1.4 |
| 46 ≤ ELM ≤ 48 | 538 | 10.8 | 18.0 | 14.1 | 38.1 | 81.0 | 16.5 | 2.4 |
| ELM ≤ 44 | 2,314 | 3.7 | 8.8 | 10.2 | 54.4 | 77.1 | 21.8 | 1.1 |
| Other | 11,668 | 26.7 | 27.3 | 21.6 | 5.9 | 81.5 | 16.2 | 2.3 |
| Total | 18,934 | 21.9 | 25.2 | 21.0 | 11.7 | 79.9 | 17.7 | 2.3 |
| Pre-baccalaureate | | | | | | | | |
| ELM ≥ 50 | 105 | 15.2 | 18.1 | 11.4 | 41.0 | 85.7 | 14.3 | 0.0 |
| ELM ≤ 50 | 11,978 | 9.1 | 12.6 | 11.0 | 48.3 | 80.9 | 12.6 | 11.0 |
| 46 ≤ ELM ≤ 48 | 1,597 | 9.8 | 15.0 | 11.1 | 47.0 | 83.0 | 16.3 | 0.7 |
| ELM ≤ 44 | 10.381 | 9.0 | 12.2 | 10.9 | 48.5 | 80.6 | 17.8 | 1.5 |
| Other | 4,635 | 7.7 | 10.6 | 10.4 | 52.3 | 81.0 | 17.6 | 1.4 |
| Total | 16,718 | 8.8 | 12.1 | 10.8 | 49.4 | 81.0 | 17.6 | 1.4 |
| Grand Total | 35,652 | 15.8 | 19.1 | 16.2 | 29.4 | 80.4 | 17.7 | 1.9 |

Source: Educational Testing Service. (2010). The California State University Entry Level Mathematics Validity Study. Unpublished Statistical Report. SR-2010-008.

scoring below the cut score who passed the course was 78% -- actually higher than the 77% at or above the cut score who passed. Students who scored *just below* the cutoff (81% scoring 46-48), as well as those who scored *far below* the cutoff (71.1% scoring 44 and below) outperformed those at or above the cut score. If the ELM were a valid predictor of students who are not likely to pass a college- level course and require remedial work, then the differences in the percentages above and below the cut score would be significant. Not only are they not significant, the percentages below the cut score are *higher*. Thus, when the criteria for success is “Pass,” 77.8% of the students who scored below the cut score and would have been designated as remedial, successfully passed the baccalaureate math course without remediation, a Type II false negative error. Consistent with the emerging placement studies research, the table shows that the ELM had severe error rates in predicting student success, depending on the grades that defined success; was better at predicting students likely to earn very high grades (“As” and “Bs”), equally as effective for predicting the “C” grade, and ineffective at predicting based on Pass/Fail criteria (ETS, 2010). It was effective for predicting for the “C” grade. It is an ineffective predictor of students likely to pass or fail a college-level course (D, F, Fail) (ETS, 2010).

Table 11 shows the distribution of passing grades for each level of the ELM score. For the Pass classification, every level below the cut score had at least a 66.7% passage rate except for ELM scores below 8. Substantial percentages of students who scored below the cut score earned grades of A, B, or C, as follows: 42.9% of students with a score of 44-46 earned A, B, or C, as did 41.4% of those scoring 44; 24.7% of those scoring 42; 21.3% of those scoring 38; 17% of those scoring 36; 20.3% of those scoring 34; and 16.7% of students who scored 32.

The ETS validity study has methodological flaws, including:

***Participant selection.*** ETS did not collect data to identify the method faculty on each campus used to select the 10 sections of the lowest-level baccalaureate math courses and 10 sections of the highest-level pre-baccalaureate math courses, noting that collection of such was beyond the study’s purview (ETS, 2010).

***Determining course type.*** The study did not distinguish calculus- and non-calculus courses, or higher- and lower-developmental courses. Thus, all students enrolled in college-level courses were categorized as baccalaureate, and all students enrolled in remedial courses were categorized as pre-baccalaureate (ETS, 2010). This group compression limits analysis of student performance by course classification, but does not preclude analysis by baccalaureate or pre-baccalaureate level.

Table 11

*Distribution of Passing Grades in College Matematics Courses for Each Level of ELM Score: Total Group*

| | Baccalaureate | | | | | | | Pre-baccalaureate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELM Score | *N* | *n* Pass | % Pass | *n* A | *n* B | *n* C | *n* Credit | *N* | *n* Pass | % Pass | *n* A | *n* B | *n* C | *n* Credit |
| 80 | 31 | 28 | 90.3 | 13 | 7 | 8 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 78 | 33 | 32 | 97.0 | 15 | 8 | 8 | 1 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 76 | 40 | 35 | 87.5 | 18 | 11 | 5 | 1 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 74 | 65 | 53 | 81.5 | 24 | 16 | 11 | 2 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 72 | 65 | 55 | 84.6 | 22 | 18 | 14 | 1 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 70 | 102 | 81 | 79.4 | 34 | 23 | 22 | 2 | 2 | 2 | 100.0 | 0 | 1 | 1 | 0 |
| 68 | 119 | 100 | 84.0 | 36 | 30 | 30 | 4 | 3 | 3 | 100.0 | 0 | 1 | 0 | 2 |
| 66 | 146 | 116 | 79.5 | 38 | 46 | 28 | 4 | 1 | 1 | 100.0 | 0 | 0 | 0 | 1 |
| 64 | 281 | 237 | 84.3 | 79 | 88 | 65 | 5 | 3 | 2 | 66.7 | 0 | 1 | 0 | 1 |
| 62 | 285 | 232 | 81.4 | 69 | 89 | 69 | 5 | 4 | 4 | 100.0 | 1 | 0 | 0 | 3 |
| 60 | 398 | 296 | 74.4 | 75 | 116 | 102 | 3 | 5 | 4 | 80.0 | 2 | 0 | 0 | 2 |
| 58 | 402 | 326 | 81.1 | 75 | 131 | 112 | 8 | 8 | 8 | 100.0 | 0 | 1 | 1 | 6 |
| 56 | 601 | 464 | 77.2 | 127 | 167 | 164 | 6 | 18 | 15 | 83.3 | 3 | 2 | 3 | 7 |
| 54 | 657 | 483 | 73.5 | 103 | 179 | 188 | 13 | 23 | 20 | 87.0 | 3 | 10 | 3 | 4 |
| 52 | 559 | 396 | 70.8 | 79 | 172 | 140 | 5 | 14 | 12 | 85.7 | 1 | 1 | 4 | 6 |
| 50 | 630 | 466 | 74.0 | 86 | 188 | 184 | 8 | 24 | 19 | 79.2 | 6 | 2 | 0 | 11 |
| 46-48 | 538 | 436 | 81.0 | 58 | 97 | 76 | 205 | 1597 | 1325 | 83.0 | 157 | 240 | 178 | 750 |
| 44 | 401 | 310 | 77.3 | 30 | 71 | 65 | 144 | 1251 | 1017 | 81.3 | 119 | 181 | 168 | 549 |
| 42 | 301 | 222 | 73.8 | 22 | 41 | 44 | 115 | 952 | 765 | 80.4 | 82 | 119 | 121 | 443 |
| 40 | 255 | 190 | 74.5 | 9 | 21 | 33 | 127 | 968 | 811 | 83.8 | 128 | 150 | 100 | 433 |
| 38 | 272 | 222 | 81.6 | 7 | 23 | 28 | 164 | 1019 | 882 | 86.6 | 96 | 142 | 112 | 532 |
| 36 | 193 | 143 | 74.1 | 3 | 9 | 21 | 110 | 910 | 744 | 81.8 | 114 | 122 | 102 | 406 |
| 34 | 172 | 139 | 80.8 | 6 | 14 | 15 | 104 | 904 | 736 | 81.4 | 100 | 123 | 113 | 400 |

Source: Educational Testing Service. (2010). The California State University Entry Level Mathematics Validity Study. Unpublished Statistical Report. SR-2010-008.

Table 11 (continued)

| | Baccalaureate | | | | | | | Pre-baccalaureate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELM Score | *N* | *n* Pass | % Pass | *n* A | *n* B | *n* C | *n* Credit | *N* | *n* Pass | % Pass | *n* A | *n* B | *n* C | *n* Credit |
| 32 | 168 | 127 | 75.6 | 3 | 13 | 12 | 99 | 942 | 785 | 83.3 | 86 | 147 | 106 | 446 |
| 30 | 143 | 117 | 81.8 | 1 | 8 | 6 | 102 | 814 | 658 | 80.8 | 70 | 107 | 99 | 382 |
| 28 | 77 | 62 | 80.5 | 1 | 0 | 2 | 59 | 419 | 338 | 80.7 | 26 | 34 | 31 | 247 |
| 26 | 102 | 84 | 82.4 | 1 | 0 | 1 | 82 | 622 | 493 | 79.3 | 36 | 33 | 51 | 373 |
| 24 | 63 | 50 | 79.4 | 0 | 1 | 3 | 46 | 507 | 393 | 77.5 | 30 | 35 | 40 | 288 |
| 22 | 66 | 45 | 68.2 | 0 | 1 | 1 | 43 | 417 | 308 | 73.9 | 24 | 29 | 41 | 214 |
| 20 | 36 | 24 | 66.7 | 0 | 1 | 0 | 23 | 263 | 172 | 65.4 | 10 | 14 | 21 | 127 |
| 18 | 27 | 18 | 66.7 | 1 | 0 | 0 | 17 | 175 | 126 | 72.0 | 9 | 13 | 13 | 91 |
| 16 | 15 | 12 | 80.0 | 0 | 0 | 0 | 12 | 121 | 89 | 73.6 | 3 | 7 | 9 | 70 |
| 14 | 13 | 9 | 69.2 | 0 | 1 | 3 | 5 | 68 | 38 | 55.9 | 1 | 5 | 7 | 25 |
| 12 | 6 | 5 | 83.3 | 0 | 0 | 0 | 5 | 24 | 13 | 54.2 | 0 | 4 | 0 | 9 |
| 10 | 1 | 1 | 100.0 | 0 | 0 | 0 | 1 | 4 | 2 | 50.0 | 0 | 0 | 0 | 2 |
| 8 | 1 | 1 | 100.0 | 1 | 0 | 0 | 0 | 1 | 1 | 100.0 | 0 | 1 | 0 | 0 |
| 6 | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 2 | 2 | 2 | 100.0 | 0 | 0 | 2 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 | 0 | 0 | 0 |
| Total | 7266 | 5619 | 77.3 | 1036 | 1590 | 1462 | 1531 | 12083 | 9786 | 81.0 | 1107 | 1525 | 1324 | 5830 |

Source: Educational Testing Service. (2010). The California State University Entry Level Mathematics Validity Study. Unpublished Statistical Report. SR-2010-008.

***Method of course placement.*** ETS did not collect data on the method(s) used to place students into courses. The study assumed students with ELM scores were placed based on their scores. Students without ELM scores were assumed to have been placed by other means (e.g., ELM exemption, instructor exception, self-selection), and were categorized as "Other." Students' ELM scores are not in question, nor is their course enrollment. Thus, the limitation does not prohibit analysis of the relationship between ELM scores and final course grades.

***Incomplete empirical analysis***. While the study used logistic regression to analyze the probability of passing the ELM using SAT math scores and ACT math scores as predictors, it did not use a regression model fitted to the data to predict success as defined by the final course grades of A, B, or C, or as defined as Pass, which is an unknown distribution of A, B, and C, if those grades had been assigned. Such analysis would have aided decision makers in ensuring 50 is an appropriate cut score.

***Representativeness***. All 23 campuses participated in the study; however, participation was uneven across campuses (ETS, 2010).

***Instructor judgments***. Instructors' judgments about whether students were properly placed in their course were collected at the end of course or after grades were awarded, as opposed to during the 4th or 6th week on quarter and semester campuses, respectively, when judgments would have been based on students' entering math skills (ETS, 2010).

***Generalizability***. ETS cautioned against generalizing the findings to the system as a whole (ETS, 2010).

## Significance of the Study

This study addressed a major impediment to the academic preparation of students transitioning from high school to college created by disconnected policies and learning expectations between the sectors. Little research has been conducted or published on the CSU Entry Level Mathematics placement test. By examining the connection between California's new academic standards and the placement standards of the largest public university system in the world, the study will contribute to what is known about the role of college placement assessments in college remediation; the extent to which the college placement and state academic standards include and emphasize the same knowledge and skills; and how alignment of the two can inform instruction and signal clearly to students what is important to learn. The findings will inform educational policymakers and stakeholders toward removing policy roadblocks, especially disconnected secondary and postsecondary policies, toward creating an educational continuum that supports, rather than undermines, the success of students' postsecondary educational aspirations.

## Theoretical Framework

The conceptual framework for this study was systemic reform, a movement which gained momentum in the early 1980s and has continued with the adoption of the Common Core State Standards. Systemic reform has five core characteristics: 1) research-based goals for practice and organizational change; 2) ambitious standards; 3) centralized goals and decentralized delivery; 4) regular assessments of inputs, process, and outcomes; and 5) coherent, sustained change process (Clune, 1993). From these principles, four inter-related theories converged to inform alignment and provide the theoretical framework for this alignment study: systems; systemic reform; alignment; and policy coherence (see Figure 12). The theories hypothesize that increased alignment among system components increases system efficiency and effectiveness, which improves system outcomes (i.e., student learning) (Anderson, 2002; Puma, Raphael, Olson, & Hannaway, 2000; Smith & O'Day, 1991).

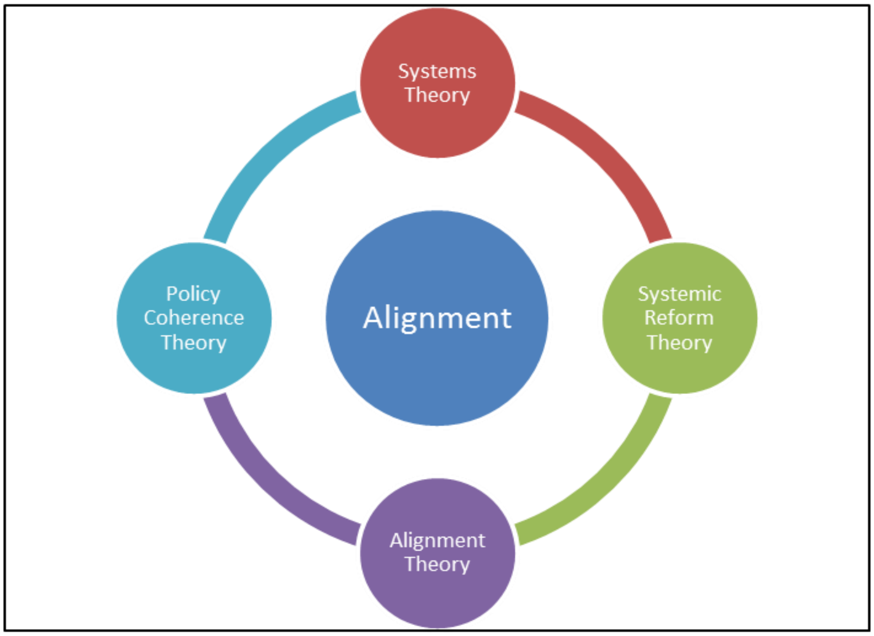


*Figure 12*. Interrelated theoretical frameworks informing alignment

**Systems Theory**

Systems theory re-conceptualizes the traditional approach to issues analysis emanating from the 16th Century that separates problems into constituent parts and studies them in isolation to understand the whole (Puma et al., 2000). The systems approach focuses on the interactions of interdependent parts to evaluate how they bring order to a network, and how changes in one part affect the whole (Puma et al., 2000). Structure and function are the two sides of systems theory. Structure encompasses how the system is organized. Function includes how actions are controlled; how communication is accomplished within subsystems and between external systems; how the system receives feedback; and how it changes in response to the external environment (Puma et al., 2000).

**Systemic Reform Theory**

Smith and O'Day's (1991) systemic reform theory posits that a coherent system of state-level educational policies can guide instructional content and quality across grade levels to create generalizable, meaningful improvements in teaching and student learning outcomes throughout the system and ensure educational equity. To significantly elevate the quality of curriculum and instruction provided to all students, systemic reform requires changes in three core areas: 1) ambitious standards for all students to provide instructional guidance and a shared vision to elevate the quality and content of instruction in all schools throughout the state; 2) aligned state education policies to provide coherence for the local design of effective instructional strategies to teach the content standards to all students; and 3) restructured governance system to provide the resources, flexibility, and support needed at the local level to design and implement effective instructional strategies for improved achievement (Goertz, Floden, & O'Day, 1996; Smith & O'Day, 1991). Policy dimensions include curriculum frameworks, instruction and materials, pre-service teacher training, in-service professional development, assessment, and accountability systems (Smith & O'Day, 1991). Curriculum frameworks refer to curricular themes and long-term objectives as opposed to specific pedagogy.

While reform efforts typically focus on the school and district-levels, it is the state that has constitutional responsibility for education (Smith & O'Day, 1991) Systemic reform contends that wide-scale generalizable improvements in student achievement can only be accomplished at the system (state) level, as only states operate at a level that can influence all components of the K-12 system and have entre into higher education to inspire coherence (Smith & O'Day, 1991). School-level reform yields piecemeal improvements to individual system components for a small number of students; is inequitable to, and marginalizes, students of color and of low socio-economic status, as school districts with large populations of such students have fewer resources to promote reforms (Goertz et al., 1995; Smith & O’Day, 1991).

Improved outcomes for all students require a massive sea change in the way the components of the fragmented educational enterprise operate together as a system (Puma et al., 2000). The strategy integrates top-down centralized state policy decisions to overcome fragmentation and bottom-up restructured governance, “simultaneously increasing coherence in the system through centralized coordination and increasing professional discretion at the school site” (Fuhrman & Massell, 1992; Puma et al., 2000; Smith & O’Day, 1990, p. 254). Systemic reform theory includes several components, including policy coherence and curriculum alignment; instruction; the opportunity to learn; teacher preparation (including pre-service training and in-service professional development); accountability and assessment; and parental and community engagement (Puma et al., 2000).

**Alignment Theory**

The goal of state educational policy is to influence what occurs in the self-contained unit of the classroom, the point of instructional delivery (Fuhrman & Elmore, 1990). Focusing on schools as the point of policy impact (as opposed to school districts), state policy has the greatest influence on classrooms when district and school policies align and converge with it to mediate or amplify the state policy (Fuhrman & Elmore, 1990). Alignment of the components of the system provide a basis for identifying the appropriate resources and practices needed, and determining whether their quality is adequate to provide all students the opportunity to learn the challenging content standards (Smith & O’Day, 1991).

Alignment has a reinforcing effect that facilitates the transfer of effective strategies among the parts and enhances coherence (Smith & O'Day, 1991).

**Policy Coherence Theory**

Policy coherence is a necessary prerequisite to systemic reform (Smith & O'Day, 1991). Broad-based reform requires systemic coherence in instructional guidance (coordinated curriculum, pre- and in-service teacher training, and assessment) linked with a reorganized governance system at all levels (Smith & O'Day, 1991). The traditional definition of policy coherence is "an objective outcome of the alignment of standards, instruction, assessment, and other policies" (Honig & Hatch, 2004, p. 1). The OECD (2013) defines it as "the systematic promotion of mutually reinforcing policy actions across government departments and agencies creating synergies towards achieving the agreed objectives" (p. 3).

The underlying premise of policy coherence theory is that education's fragmented, complex, multi-layered system of overlapping and conflicting informal and formal policies and the absence of purposeful coordination are fundamental impediments to school success (Smith & O'Day, 1991). As Smith and O'Day (1991) assert, "the fragmented policy system creates, exacerbates, and prevents the solution of the serious long-term problems in educational content, pedagogy, and support services that have become endemic to the system" (p. 237). In addition, political pressures to show immediate measureable improvements lead to a non-holistic "project" or "concept" reform approach that produces short-lived results and gives rise to educational mediocrity (Smith & O'Day, 1991, p. 237).

## Definitions

**Alignment.** Bhola, Impara, and Buckendahl (2003) defined alignment as "the degree of agreement between a state's content standards for a specific subject area and the assessments used to measure achievement of these standards" (p. 3). Similarly, La Marca (2001) defined it as the degree of match between test and subject area content as defined by academic standards. Webb (1997) defined alignment as "the degree to which expectations and assessments are in agreement and serve in conjunction with one another to guide the system toward students learning what they are expected to know and do" (p. 3).

**Assessment.** Assessment is defined as a procedure for collecting, synthesizing, and interpreting information about students' achievement to support teachers in their decision making, and to evaluate teaching, schools, and educational reforms (Herman, Webb, & Zuniga, 2005).

**Cognitive demand.** Cognitive demand, or cognitive complexity, is defined as "the level of information processing and the degree of conscious thought required to complete a task" (Lombardi, Seburn, Conley, & Snow, 2010, p. 6).

**College-readiness.** Conley's (2007b, 2010) framework of college readiness includes four key dimensions to be college- and career-ready. The first dimension, key cognitive strategies, is the disciplined approach to thinking that students must undertake, and includes problem formation and problem-solving strategies; research skills; interpretation of competing and conflicting information; communication; and precision and accuracy. The second component is key content knowledge and encompasses the structure of core academic subjects (key terms, factual information, theories, and concepts); technical knowledge and skills; challenge level; value of the knowledge to the student; attribution of success or failure to master knowledge; and effort in gaining mastery. The third element, key learning skills and techniques, embodies taking ownership of learning (e.g., goal-setting, motivation, persistence, and self-efficacy), and learning techniques (study skills and other academic behaviors). The last facet is key transition of knowledge and skills, or "college knowledge," acculturating to the college environment, understanding its norms, and navigating its systems (see Figure 13).

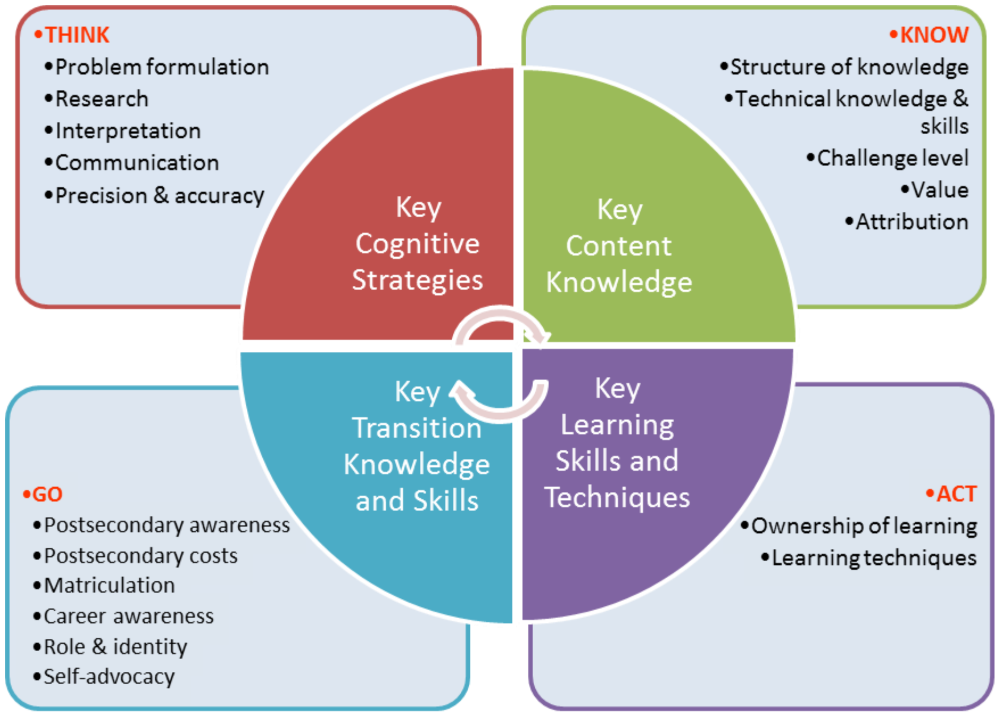


*Figure 13*. Conley's (2007b) four dimensions of college and career readiness.

**Opportunity to learn.** Opportunity to learn focuses on what occurs in the classroom and regards students' access to curriculum; in particular, content exposure, coverage, and emphasis, and the quality of instructional delivery (Stevens & Grymes, 1993). The variables are investigated to illuminate the differences in students' academic performance. Content exposure looks into whether the grade-level or subject-area core curriculum was covered. Content coverage explores time-on-task and depth of coverage. Content emphasis considers which topics were given more importance and "which students were selected to receive low or higher order skills" (Stevens & Grymes, 1993, p. 5).

Quality of instructional delivery speaks to how classroom teaching practices affect student performance. Opportunity to learn is an issue of educational (in)equity and is fundamental to understanding whether remedial students (who disproportionately are minority and low-income) have been exposed to the content on which they are tested (Stevens & Grymes, 1993). The issue challenges

> the incorrect assumption that the students [who were not exposed to the content and scored below average on norm-referenced tests] did not work hard enough or were not capable of learning the subject matter, when in fact, student performance was tied critically to the performance of their classroom teachers. (Stevens & Grymes, 1993, p. 2)

**Proficiency.** DeBray (2006) defined proficiency as the level at which a student is determined to be sufficiently educated at each grade level and upon graduation.

**Remedial/Remediation.** Conley (2010) describes the traditional definition of a remedial student as "one who fails to meet the standards for enrollment into an entry-level credit-bearing course, generally as applied to English, composition, and mathematics" (p. 5). The term has a non-specific and unscaled definition, the meaning of which varies from institution to institution. Remediation is a dichotomous determination defined most simply as below-level courses offered to college students who lack the skills necessary to perform college-level work as defined by the institution (Parsad et al., 2003).

**Standards.** Standards are goals statements of desired student learning outcomes that describe what students should know and be able to do as a result of instruction in a subject area by the end of each grade level (CCSI, 2014).

## Summary

High school and higher education are components of the pre-kindergarten-postsecondary educational system. By design, the two sectors have different missions, goals, governance structures, centers of authority, and funding sources. The fractious, multi-layered complexity of the state-controlled educational system creates unaligned, and sometimes conflicting, policies that undermine the efforts of students who follow the policies of one sector only to be noncompliant with the policies of the other. The inconsistent policies send confusing signals to students, parents, teachers, and administrators who are unsure of the specific knowledge and skills required to be prepared for college, relegating more than half of first-year students to remedial coursework.

To improve the quality of education and student outcomes, the national focus on educational reform has shifted from incremental, school- and district-level reform to a systems perspective. The development of content and performance standards, and alignment of the educational system to the standards, is the core of systems reform, or standards reform, which was undergirded by the seminal work of Smith and O'Day's (1991) systemic reform theory. The landmark 2010 adoption of K-12 Common Core State Standards in ELA and mathematics by the majority of U.S. states territories, and the scheduled 2014 implementation of assessment of the standards, has important implications for higher education and systems outcomes. This alignment analysis research study contributes to emerging research on the Common Core standards by examining the relationship between the standards and the college placement examination used by the largest 4-year public university system in the world, on which scant research has been conducted or published. This study is organized into five-chapters.

Chapter 1 introduced the problems of remediation and declining college degree completion; their relationship to college-readiness and impact on global economic competitiveness and future economic workforce needs; the difference in secondary and postsecondary perceptions of college-readiness; and higher education's use of placement exams to determine college-readiness. The research questions were introduced and the study placed in the context of California's public higher education system. Four inter-related theoretical frameworks operate within the conceptual framework of systemic reform to inform the study. The chapter finishes with a definition of terms used throughout the dissertation.

Chapter 2 reviews existing curricular alignment research literature, focusing on the effect of alignment on student learning outcomes; reviewing the most widely used alignment analysis methods and models, and reviewing previous standards-assessment alignment studies that used the protocol selected for the current study, the Webb (1997, 1999) alignment methodology. An overview of issues and limitations completes the chapter.

Chapter 3 details the study's methodology. Described in this chapter are the mixed methods research design; expert sample participant selection; alignment measures and criteria; automated data collection instrument; detailed procedures, including subject matter expert training, and convergent consensus. Data analysis and issues and limitations of the protocol are discussed.

Chapter 4 presents the quantitative and qualitative findings and chapter 5 presents a discussion of the research findings of the degree of content and cognitive alignment between the standards and the assessment, including reviewer agreement and inter-rater reliability.

# CHAPTER 2: REVIEW OF THE LITERATURE

The purpose of this study was to determine the extent to which the California Common Core Content Standards for Higher Mathematics (9-12) were aligned with the California State University system's Entry-Level Mathematics placement assessment. This chapter provides an overview of the literature on curricular alignment; in particular, the alignment between secondary academic standards and college expectations. The chapter begins with the importance of aligning curriculum components. Section 2 discusses the effect of alignment on student learning. Section 3 reviews alignment analysis models and methods. Section 4 presents previous alignment studies using the method employed in the current study. The final section discusses issues and limitations of alignment analyses.

## Alignment of Curriculum Components

Curriculum components – the intended, taught/enacted, and tested curriculum -- are inter-related. Alignment of rigorous academic standards, assessment, and curriculum is a core component of standards-based education, but in and of itself does not lead to improved student learning outcomes and college-readiness (Hess, Jones, Carlock, & Walkup, 2009). Improvements in student learning depend on how well assessment, curriculum, and instruction are aligned and reinforce a common set of learning goals, and on whether teacher instruction, pedagogical activity, and the design of teaching and learning shift in response to the information gained from assessments to elicit the desired learning outcomes (Biggs, 1996; Hess et al., 2009). Figure 14 illustrates how curriculum components connect, the type of information solicited from studying the alignment between different curriculum components, and how instruction is implicit in, and essential to, alignment between standards and assessment. Curriculum alignment studies between standards and assessments, such as the present study, are *content validity* studies that explore the extent to which the assessment measures what was intended to be taught. Studies between assessments and instruction elicit two types of information, depending on the question's point of origin. When the question starts from the point of the assessment, the analysis is an opportunity-to-learn study. There, the question is whether what is being *tested*, is being *taught:* that is, do students have the *opportunity to learn* what is being *tested*? When the question stems from the point of instruction, the study is one of *content coverage*, examining whether what is being *taught*, is what is being *tested*; that is, are we *teaching* what is being *tested* (Anderson, 2002)?

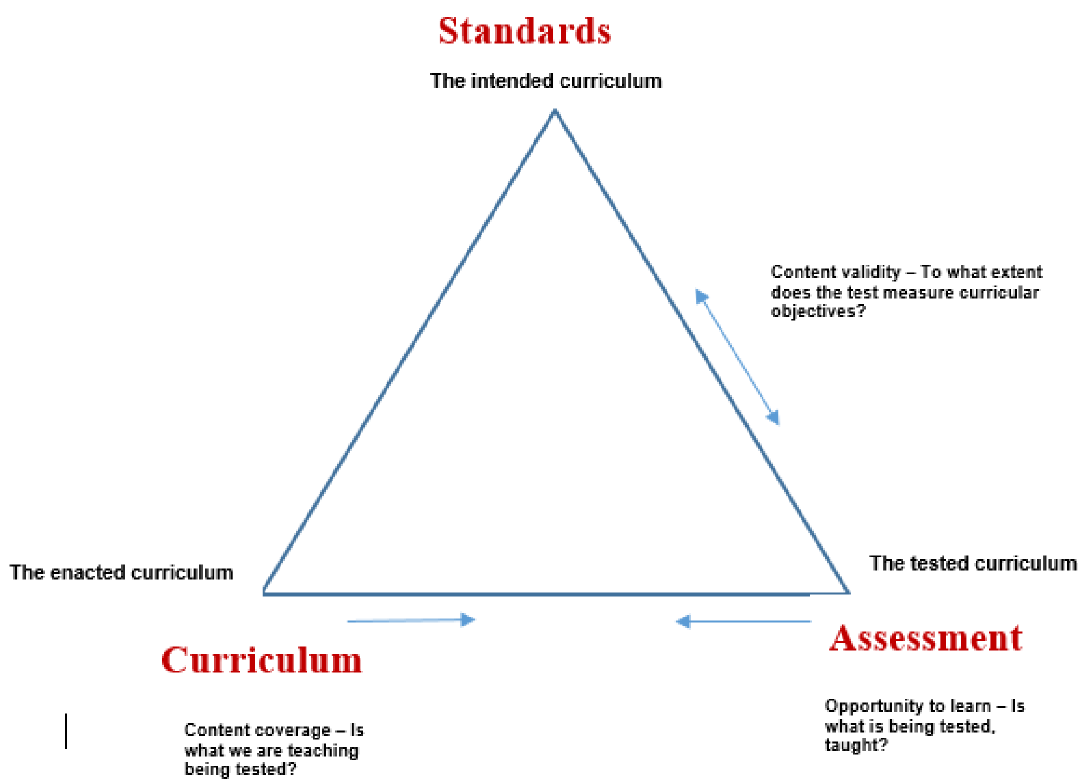


*Figure 14*. Alignment of curriculum components. Anderson, (2002).

## The Effect of Alignment on Student Learning

While the principle of instructional alignment is well-established in instructional design literature dating back to Gilbert (1962), and conventional wisdom recognizes that effective teaching requires congruence between instruction and assessment (instructional congruence), the *magnitude* of the effect of alignment; and thus, its importance, has not been fully discussed and is not widely understood (Cohen, 1987). Cohen's (1969) standardized effect size (Cohen's *d*) provides a framework for elucidation.

Cohen's (1969) effect size measures, in standard deviation units, the difference the effect of a construct makes on a treatment and comparison group. Cohen's (1969) conventions specified $p = .05$ as the level of significance, and d=.2, d=.5, and d=.8 as small, medium, and large effects, respectively. According to Cohen (1987), traditional teaching as occurs in the typical classroom, described as unaligned instruction, produces .25 to .50 sigma effects, associated with increasing learning by one-quarter to one-half standard deviations. In several doctoral studies directed by Cohen (1987) using analysis of variation (ANOVA) to test the degree of the effect of instructional alignment on student performance, Koczor (1984), Tallarico (1984), Fahey (1986), and Elia (1986) found that when curriculum and assessment were aligned, the effect of even modest instruction (30, 45, 60, and 90 min) on student performance routinely was *four times greater* than when instruction was not aligned (1.5-3.4 sigma versus .25-.50 sigma) (Cohen, 1987).

Koczor (1984) studied high-achieving fourth-graders to test the alignment effect across multiple fourth-grade skills. Over a period of six days, students were presented one 45-min typical fourth-grade lesson per day, each cognitively and instructionally unrelated. Immediately following each lesson, students were given a post-test, the format of which differed each day. The post-test for one group was aligned to the lesson's instruction while the post-test for the misaligned treatment group had a minor variation. In one of the lessons, students were taught to how write Arabic numerals for Roman numerals where the Roman numeral always was presented first and the student had to write the corresponding Arabic numeral. The post-test for one group was aligned to the lesson, presenting the Roman numeral first, while the post-test for the misaligned treatment group presented the Arabic numeral and the student was required to write the Roman numeral, a minor variation which generated the misalignment. The study found the misalignment accounted for a 40% difference in post-test scores. The effect size for the lower aptitude students (mean 4.4 grade level reading) was as high as 1.10 while the effect size for average aptitude students was 2.74 sigma. Among high-aptitude students (mean 8.6 grade level reading), the standard deviation was 1.3 sigma (Cohen, 1987).

In Tallarico's (1984) study of "test wiseness effects" (using the test characteristics and formats to improve test score), second graders were divided randomly into either a "best answer" or "item stem cue" treatment group and one control group in a multiple-choice norm-referenced standardized test of reading achievement (p. 2; Cohen, 1987, p. 18). The best answer treatment group was instructed in intent consideration; the item stem cue group received instruction in how to pre-read an item stem as a cue to understanding; and the control group received placebo instruction. In a test administered after 30 min of instruction, 10 min of demonstration, and 20 min of practice, the intent consideration-aligned treatment had a 1.3 sigma effect and with aligned instruction, low-achieving students' average score was 85% higher than high-aptitude students in the unaligned instruction group, substantially overcoming the gap between low- and high-aptitude students (Cohen, 1987; Tallarico, 1984).

In Fahey's (1986) 3x2x3 mixed ANOVA study of community college students stratified by aptitude, there was no difference between aligned and unaligned instruction when tasks were easy (Cohen, 1987). The alignment effect increased, however, as the level of task difficulty increased, to the extent that lower-aptitude students in the aligned instruction treatment group outperformed higher aptitude students in the unaligned instruction control group. After just 90 min of instruction, with an observed effect size of 1.2 sigma, the power of aligned instruction was strong enough to eradicate the anticipated aptitude gap, "demonstrat[ing] that lower aptitude students can successfully perform higher cognitive tasks when we align instruction" (Cohen, 1987, p. 18).

Elia (1986) analyzed the individual and interactive effects of two alignment treatments on low-SES public school fourth-graders who received instruction in one format and were tested in another format. Students were taught eight vocabulary words and four word variants, and synonyms through three different conditions: phrases one day; sentences another day; or paragraphs still another day. Between instructional days, students were tested on the words or their variants, with one-third of the group tested in the format of instruction, and the other two groups tested in the formats unaligned with the day's instruction. The study resulted in an overall effect size of .91sigma with (mis)alignment explaining 23% of the total variance, and a 1.76 sigma alignment effect in the phrase condition, with (mis)alignment explaining 16% of the variance (Elia, 1986).

Cohen (1987) concluded from these studies that: 1) a 4-to-1 Effect was routine with instructional alignment; 2) content of instruction is more important than pedagogy; 3) instructional alignment is more important for lower achieving students than for higher achieving students; and 4) instruction should test what it teaches and teach what it tests. Against this backdrop, the current study of the alignment between the CA CCSSM for higher mathematics and the ELM will inform whether high school-higher education expectations are creating the opportunity to align instruction to elicit the type of learning outcomes empirically shown to result from aligned instruction. Just as students are held accountable for learning, educational institutions and the educational system must be accountable for ensuring they provide students the opportunity to learn what is expected in the standards (Anderson, 2002).

## Curriculum Alignment Methods and Models

Sequential development, expert review, and document analysis are the three most generally used methods to evaluate the alignment of standards to assessments, either independently or in combination (Case & Zucker, 2005). In sequential development, standards are developed first, with widespread input from educational stakeholders, after which they are used as blueprints to develop assessments. This methodology is utilized to ensure linkage between the standards and a sufficient number of assessment items (Case & Zucker, 2005). The assessments developed by the Smarter Balance Consortium to align with the CCSS were developed subsequent to the development of the standards.

With expert review, a panel of subject matter and assessment experts makes judgments about the degree of alignment between the standards and assessment items against established criteria (Case & Zucker, 2005). Prior to analyzing alignment, the reviewers are trained in the document analysis also utilizes content experts who review and code the contents of test forms and standards, for example, to compare quantitatively along an alignment index.

Expert review is common to all three of the most widely used alignment analysis protocols: the Webb, Achieve, and Survey of the Enacted Curriculum (SEC) models. Bhola et al. (2003) categorized alignment models in terms of the complexity of their alignment criteria. The simplest are low-complexity models that define alignment along a single indicator as the extent to which test and standards items match (Bhola et al., 2003). Content experts such as content area teachers, higher education faculty, and education specialists, determine the match using a Likert scale ranging from no match to complete match. Moderate complexity models add cognitive complexity to item match. Experts first code the standards, then the assessment items, into a two-dimensional matrix, and convert the results into quantitative data (Bhola et al., 2003). In high-complexity models, item match and cognitive rigor are but two of multiple criteria used to measure alignment. The SEC is a moderate-complexity model. The Webb (1997, 1999) and Achieve models operationalize the high-complexity category (Bhola et al., 2003). All three models are detailed below.

## The Webb Alignment Model

Webb (1997, 1999) conceptualized a comprehensive model of alignment along five dimensions: content focus; articulation across grades and ages; equity and fairness; pedagogical implications; and system applicability (Martone & Sireci, 2009). In alignment analysis studies, only the content focus dimension is applied, and of the six subcategories of the dimension, only the first four areas have been utilized: 1) categorical concurrence; 2) depth of knowledge; 3) range of knowledge; and 4) balance of representation (Martone & Sireci, 2009).

**Categorical concurrence**. This dimension is comparable to item match and is the minimum criteria required for alignment analysis (Martone & Sireci, 2009). The criterion requires that at least some component of the broad content standard is represented in the assessment, with a threshold of at least six assessment items matched to the standard across subject matter experts (Bhola et al., 2003).

**Depth of knowledge**. The criterion pertains to cognitive complexity, applies to specific objectives within the broad standards, and requires that the assessment item is at least at the same level of cognitive complexity as the objective. Table 12 details Webb's (1999) four levels of cognitive complexity. Working together, content experts discuss and assign a cognitive level to each specific objective within the standard. Then, working independently, the experts rate the cognitive demand of each assessment item related to the standard. To meet this alignment criterion, at least 50% of the assessment items corresponding to the objective must be at least at the same cognitive level as the objective (Bhola et al., 2003; Martone & Sireci, 2009; Webb, 1997, 1999).

**Range of knowledge.** Recognizing that standards may contain multiple content domains, this subset measures consistency of the breadth of the standards and requires that at least 50% of the objectives are represented by at least one assessment item to ensure that students are tested on at least half of the knowledge domain (Bhola et al., 2003; Martone & Sireci, 2009). For example, the range of knowledge criterion would not be met for a standard that required the correct usage of writing conventions with objectives pertaining to spelling, punctuation, and grammar if the assessment item only related to spelling (Bhola et al., 2003).

**Balance of representation**. The fourth subcategory measures how evenly the assessment items are distributed across objectives (Bhola et al., 2003). On a scale of 0 to1, an index near 0 indicates either that only a few objectives are being measured or that assessments are clustered around only a few objectives, while an index near 1 indicates a balanced assessment where most of the objectives are

Table 12

*Webb's General Descriptions for Depth of Knowledge Levels*

| **Level** | **Description** |
|---|---|
| Level 1: Recall | This level includes the recall of information such as a fact, definition, term, or simple procedure, as well as performing a simple algorithm or applying a formula. |
| Level 2: Skill/Concept | This level includes the engagement of some mental processing beyond a habitual response. A Level 2 assessment item requires students to make some decisions as to how to approach a problem or activity. Key words that distinguish a Level 2 item or task include "classify," "organize," "estimate," "make observations," "collect and display data," and "compare data." |
| Level 3: Strategic Thinking | This level includes items that require reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. In most instances, requiring students to explain their thinking is a Level 3 attribute. Students might also be required to make conjectures or determine a solution to a problem with multiple correct answers at this level. |
| Level 4: Extended Thinking | This level includes items that require complex reasoning, planning, developing, and thinking most likely over an extended period of time. At Level 4, the cognitive demands of the task should be high, and the work should be very complex. Students should be required to make connections both within and between subject domains. Level 4 activities include designing and conducting experiments, making connections between a finding and related concepts, combining and synthesizing ideas into new concepts, and critiquing literary pieces and experimental designs. |

Source: Roach, Niebling, and Kurz, 2008 (from "An Analysis of the Alignment Between Mathematics Standards and assessments for Three States," by N.L. Webb, 2002, paper presented at the annual meeting of the American Educational Research Association, April, New Orleans, LA.).

being measured by a nearly equal number of assessment items (Bhola et al., 2003). Webb (1999) suggested that ≥ .07 was required to meet the alignment threshold (Bhola et al., 2003).

**Achieve**

Similar to the Webb (1997, 1999) model, the Achieve model evaluates alignment along multiple criteria: 1) accuracy of the test blueprint; 2) content centrality; 3) performance centrality; 4) challenge; 5) balance; and 6) range (Bhola et al., 2003; Roach et al., 2008; Rothman, Slattery, Vranek, & Resnick, 2002). Accuracy of the test blueprint ensures that each assessment item corresponds to at least one standard (Bhola et al., 2003). Content centrality and performance centrality are consistent with Webb's (1997, 1999) categorical concurrence and depth of knowledge complexity, respectively. The challenge criterion includes source and level of challenge, and seeks to determine both whether the challenge comes from the standard or an extraneous factor, and whether it spans the range of difficulty for the target grade (Bhola et al., 2003). While balance in the Webb (1997, 1999) model focuses on even distribution across standards, the Achieve model focuses on whether the emphasis on the knowledge or skill is the same in the assessment as in the linked standard (Bhola et al., 2003; Rothman et al., 2002). Range measures whether the knowledge and skills represented in an assessment's items are a representative sample of those in the standard's content domain (Bhola et al., 2003).

Unique to the Achieve protocol is the requirement that the expert reviewers take the assessment being reviewed to gain an understanding of its demand and focus; the initial item-level blueprint analysis; the qualitative judgments under the balance criterion regarding whether objectives are over- or under-assessed using categories of *good*, *appropriate*, *fair*, or *poor;* and the written evaluation of the level of challenge (Roach et al., 2008; Rothman et al., 2002).

**Survey of the Enacted Curriculum**

Porter and Smithson's (2002) Survey of the Enacted Curriculum focuses on what occurs in the classroom. The model is useful to investigate assessment-to-assessment, assessment-to-instruction, and instruction-to-instruction alignment within and across states, districts, or schools. A distinguishing feature of the model is that, irrespective of whether assessment, standards, or instructional content is being examined, the model maps the content to a common language framework which facilitates direct comparisons across instruments (Roach et al., 2008). For collection of instructional data, the SEC uses end-of-year teacher surveys of the emphasis they placed on topics taught during the previous year and the emphasis placed on specific cognitive demands using the topic-by-cognitive demand framework. Expert reviewers code the content into a topic-by-cognitive demand matrix for each instrument and compare the matrices to produce a single alignment index statistic from 0 to 1.0. A unique feature of this model is the display of data using topographical maps to highlight points of coverage, emphasis, alignment, misalignment (Roach et al., 2008). Table 13 provides an overview and comparison of the three alignment models, comparing the instructional components evaluated, use of expert reviewers, alignment process, and breadth and depth criteria.

## Previous Alignment Studies

Literature is rich with existing studies using quantitative and qualitative methods for alignment analysis (e.g., Brown & Conley, 2007; Brown & Niemi, 2007; Conley, Drummond, de Gonzalez, Seburn, Stout, & Rooseboom, 2011; D'Agostino et al., 2008; Porter, 2002; Shelton & Brown, 2008; Rothman et al., 2002; and Webb, 1997, 1999, 2002). The current standards-to-assessment study to evaluate the correspondence between the newly implemented Common Core standards and the California State University math placement test is conceptualized as building upon and extending the alignment work of Conley et al. (2011); Brown and Conley (2007); Shelton and Brown (2008); Brown and Niemi (2007); and. Conley et al. (2011) benchmarked the Common Core against five different sets of standards, including two top-performing states, a rigorous set

Table 13

*Overview of Major Alignment Models*

| | **Webb** | **Surveys of Enacted Curriculum** | **Achieve** |
|---|---|---|---|
| **Components Evaluated for Alignment** | Assessments<br>Standards | Assessments<br>Standards and Curricular Materials<br>Classroom Instruction | Assessments<br>(Items and Item Sets)<br>Standards |
| **Raters or Evaluators** | Alignment panel of 6 to 8 educators with subject area expertise | Individual teacher (Classroom Instruction); Alignment panel of 3 or more content area specialists | Alignment panel of 3 or more content area specialists |
| **Alignment Evaluation Process** | 1. Panel members are trained to recognize and apply four depth-of-knowledge (DOK) levels.<br>2. Panel reaches consensus on DOK level ratings for objectives from content standards.<br>3. Panel members then independently rate the DOK level and corresponding objective from standards for each assessment item. | 1. Teachers complete Survey of Enacted Curriculum ratings at the end of the year. Survey includes ratings level of coverage for topics and subtopics taught and the level of cognitive demand for tasks in each topical area.<br>2. Panel members rate the level of coverage for topics and subtopics and cognitive demand of tasks and activities for standards, curricular materials, and assessments. | 1. Expert panels make consensus judgments regarding the quality of the content and performance match between individual test items and their respective standards. Each item is further evaluated regarding the source of its difficulty.<br>2. Panels then judge whether entire item sets assess the respective standards with a comparable emphasis and range of expectations. Each set of items is further evaluated regarding the grade-level appropriateness for its span of difficulty. |
| **Breadth Criteria** | Categorical Concurrence<br>Range of Knowledge<br>Balance of Representation | Topic and subtopic categories<br>Emphasis ratings within topics | Content Centrality (Items)<br>Range (Item Sets)<br>Balance (Item Sets) |
| **Depth Criteria** | DOK Consistency | Cognitive demand categories<br>Emphasis ratings within cognitive demand | Performance Centrality (Items)<br>Source of Challenge (Items)<br>Level of Challenge (Item Sets) |

Source: Roach, Niebling, & Kurtz, 2008.

of standards, an international standard, and standards specifically developed as college-ready. Brown and Conley (2007) focused on alignment with the college-readiness standards at top-tier, selective research universities across the nation. Brown and Niemi (2007) and Shelton and Brown (2008) focused on alignment with community college expectations in California. The current study focused on 4-year public university college readiness standards in California, an area of research missing from the alignment studies series. All of the studies used the Webb (1997, 1999) methodology.

**Conley, Drummond, de Gonzalez, Seyburn, Stout, and Rooseboom (2011)**

Conley et al. (2011) adapted Cook and Wilmes's (2007) standards-to-standards derivation of Webb's (1997, 1999, 2002) assessment-to-standards alignment methodology to compare the exit-level Common Core State Standards in ELA and math with each of five sets of existing standards identified as exemplary state standards, rigorous, or written as college- and career- ready, including:

- California's 1997 content standards for $11^{th}$-$12^{th}$ grade band ELA and $8^{th}$-$12^{th}$grade band math;
- The Massachusetts $11^{th}$-$12^{th}$ grade ELA curriculum frameworks released in 2001 and math curriculum frameworks released in 2000;
- the Texas College and Career Readiness Standards in ELA, math, and cross-disciplinary standards, developed collaboratively by a postsecondary education agency and K-12 educators, released in 2008;
- the Knowledge and Skills for University Success (KSUS), developed as college-ready standards for select American research universities via a convergent consensus process with more than 400 Association of

American Universities- (AAU) member faculty who taught entry-level courses, released in 2003 (Brown & Conley, 2007); and

- the International Baccalaureate (IB) Diploma Programme 10th-12th grade ELA and math standards, developed by the Educational Policy Improvement Center (EPIC) at the University of Oregon's Center for Educational Policy Research (CEPR) (Conley et al., 2011).

A panel of 9 ELA and 7 math secondary and postsecondary experts with standards alignment experience were recruited to review and rate the relationship between the standards along three alignment indices: 1) categorical concurrence (content match/overlap); 2) depth of knowledge consistency (cognitive demand); and 3) breadth of coverage (broad match) (Conley et al., 2011). Following the Webb (1997, 1999) protocol, the respective ELA and math panels trained collectively, practicing assigning DOK ratings to each standard; matching Common Core and comparison standards; and reaching consensus on decision rules to guide ambiguous situations. After training and assigning DOK ratings to the Common Core standards, each rater individually completed two tasks: 1) assigned a DOK rating to each comparison standard; and 2) determined the content match between each comparison standard and the Common Core standards. To ensure that alignment focuses only on the statements' central content, the Webb (1997, 1999) protocol permits up to three Common Core standards to be matched to each comparison standard, and requires that the standards match fully. No partial matches are permitted (Conley et al., 2011).

Figure 15 shows the Common Core ELA and literacy standards for grades 11 and 12's 113 ratable statements, organized into eight strands of related standards and sub-standards. Sub-standards were rated on the same level as standards.

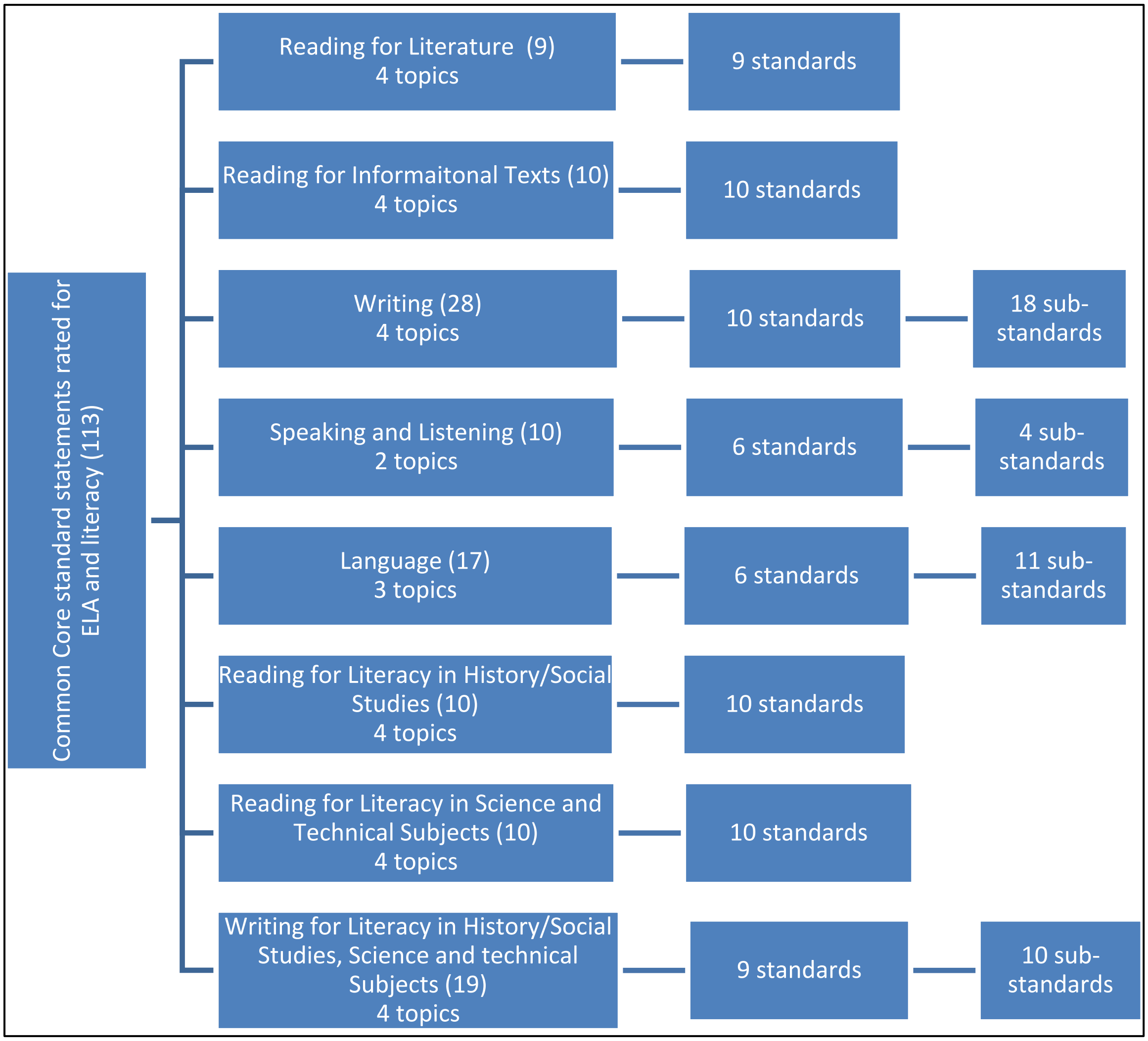


*Figure 15*. Common Core English Language Arts and Literacy standards for grades 11 and 12: Number of rated statements. Source: Conley et al. (2011).

The number of standards in each comparison set for ELA and literacy are shown in Table 14.

Table 14

*Descriptive Information for the Five Comparison Standard Sets for English Language Arts and Literacy*

| **ELA comparison standards sets** | **Number of comparison standards** |
|---|---|
| California ELA standards for grades 11-12 | 108 |
| Massachusetts ELA standards for grades 11-12 | 41 |
| Texas ELA and cross-disciplinary college and career-readiness standards | 89<br>(45 are cross-disciplinary) |
| Knowledge and Skills for University Success ELA college and career-readiness standards | 73 |
| International Baccalaureate ELA standards for grades 10-12 | 49 |

Source: Conley et al. (2011)

The Common Core math standards for high school (grades 9-12) include domains and clusters under each of the six conceptual categories (Number and Quantity; Algebra; Functions; Modeling; Geometry; and Statistics and Probability). Standards and sub-standards were rated on the same level. The Modeling conceptual category was excluded because it is integrated into each of the other categories, resulting in 192 ratable statements, including standards and sub-standards, as shown in Figure 16. Table 15 outlines the number of comparison standards in each of the comparison standards sets.

The study found substantial correlation between the Common Core and comparison standards with greater alignment for mathematics than for ELA and literacy (Conley et al., 2011). For ELA and literacy, 36 of 40 of the analyses met the categorical concurrence criterion and 17 of 36 were rated at the same of higher

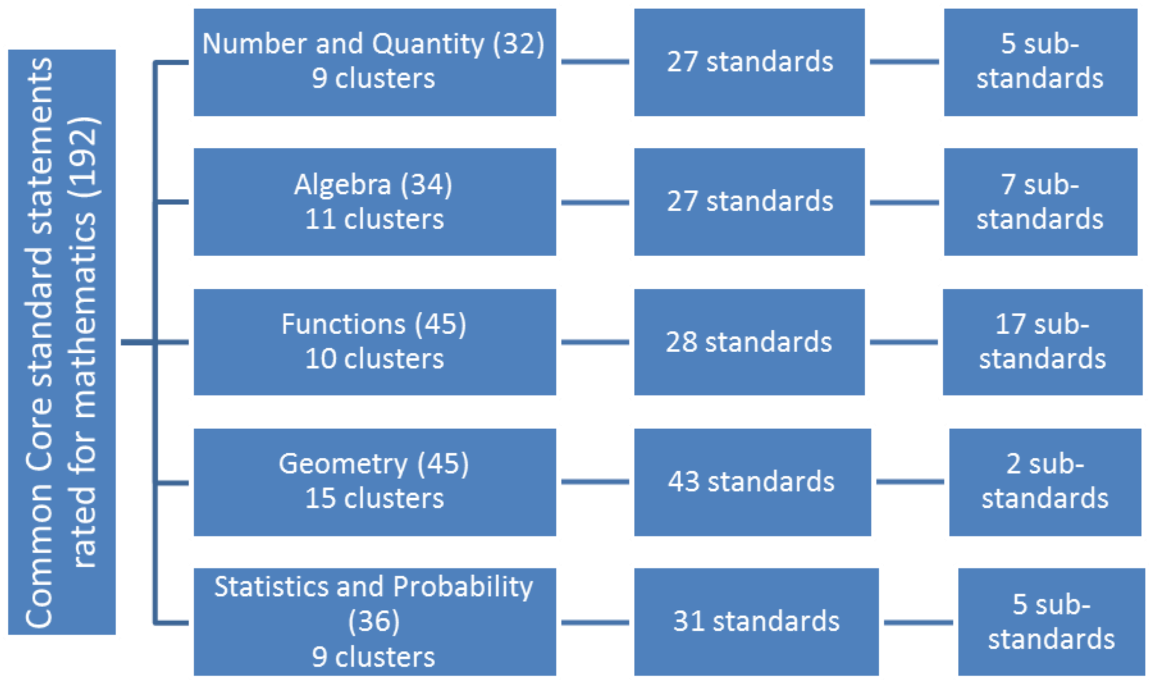


*Figure 16*. Common Core mathematics standards for high school: Number of rated statements. Source: Conley et al. (2011).

Table 15

*Descriptive Information for the Five Comparison Standard Sets for Mathematics*

| **Mathematics comparison standards sets** | **Number of comparison standards** |
|---|---|
| California mathematics standards for grades 8-12 | 185 |
| Massachusetts mathematics standards for grades 9-12 | 103 |
| Texas mathematics and cross-disciplinary college and career-readiness standards | 115 (45 are cross-disciplinary) |
| Knowledge and Skills for University Success mathematics college and career-readiness standards | 83 |
| International Baccalaureate ELA standards for grades 10-12 | 189 |

Source: Conley et al. (2011)

cognitive level as the Common Core standard (Conley et al., 2011). For breadth of coverage, 37 of 40 strand analyses showed strong coverage. For mathematics, all 25 of the conceptual category level analyses met the categorical concurrence criteria and 19 of the 25 were at the same cognitive level as the Common Core standards (Conley et al., 2011). Although each of the Common Core standards did not have a match with every standard in every set of comparison standards, the topics had strong coverage. The findings suggest general agreement between Common Core and exemplary standards about what is important for students to know and be able to do in ELA, literacy, and mathematics to be college-and career-ready. The study suggests further analysis at the individual state level (Conley et al., 2011).

**Brown and Conley (2007)**

In a three-step alignment rating process using expert reviewers to determine the relationship with standards of college readiness, Brown and Conley analyzed 30 high school exit-level math assessments and 30 high school exit-level ELA assessments from 20 states that use state high school assessments for college placement purposes. California was not among those states. High school and college faculty content experts who had direct experience with high school assessments or teaching an entry-level college course applied a slightly modified methodology (Webb, 1997, 1999) to analyze the assessments against the Knowledge and Skills for University Success (KSUS) standards. ELA standards topics included reading and comprehension, writing, critical thinking, and research skills. Math standards topics covered computation, algebra, geometry, math reasoning, trigonometry, and statistics (Brown & Conley, 2007).

The standards were rated for content coverage breadth and depth, and cognitive complexity. In addition to using Webb's (1997, 1999) content-focused alignment criteria of categorical concurrence, depth of knowledge, range of knowledge, and balance of representation, a new metric, the Summary Alignment Index Value (SAIV), was introduced to consolidate the indices into one alignment index score (Brown & Conley, 2007). Applying Webb's (1997, 1999) four alignment criteria to each of the six KSUS math topics resulted in 24 alignment measures for each of the 30 state math assessments, and the four criteria for the four KSUS ELA topics resulted in 16 alignment measures for each of the 30 ELA assessment. In addition to reporting these multiple measures for the 60 state assessments, the study also introduced the single SAIV score as a possible shorthand measure for use when large numbers of assessments are being reviewed, subject to further study and refinement (Brown & Conley, 2007).

The reviewers utilized a 5-point Marzano (2001) scale of retrieval, comprehension, analysis, utilization, and goal-setting/monitoring to assign a depth of knowledge rating to each KSUS item, and then to each assessment item within the math and ELA disciplines. In the third step, the reviewers analyzed each assessment item against each KSUS standard to determine whether the assessment item addressed each standard (Brown & Conley, 2007). For each reviewer, the resulting standards-by-assessment item matrix for each state assessment identified which assessment item addressed which standard, the number of standards addressed by an assessment item, and which standards were not addressed by assessment items (Brown & Conley, 2007). Training sessions consisted of the reviewers collectively rating and discussing sets of 10 assessment items, and establishing scoring criteria and decision rules. The rules then were applied consistently in the ratings sessions during which each test was rated by at least five reviewers working independently, including a mixture of high school and college faculty (Brown & Conley, 2007).

Webb's (1997, 1999) categorical concurrence metric is the total number of matches between assessment items and standards objectives (Brown & Conley, 2007). The suggested benchmark is a minimum of six assessment items aligned to each standard. The depth of knowledge consistency criterion requires at least half of the assessment items to be at the same or higher level of cognitive complexity as the standards (a .50 benchmark). To obtain a summary range of knowledge value, the metric averages across raters the percentage of objectives in a standard each rater rates as being addressed by the assessment items. Alignment requires that an assessment address at least half of the objectives in a standard (a .50 benchmark). ELA standards included 6 critical thinking, 11 research skills, 26 reading and comprehension, and 30 writing objectives while math included 3 statistics, 4 trigonometry, 11 computation, 15 geometry, 24 algebra, and 27 mathematical reasoning objectives (Brown & Conley, 2007). The balance of representation benchmark requires a .70 threshold to indicate even distribution (overlap) of assessment items across the standards. The SAIV metric is the weighted average of the three alignment indices that range from 0 to 1; namely, depth of knowledge consistency, range of knowledge, and balance of representation (Brown & Conley, 2007). An SAIV value of at least.563 is required to indicate adequate summary alignment for a standard. To compare assessments across states, a summary value ranging from 0 to 1.0 for each assessment was calculated.

The study found uneven, moderate alignment with a subset of standards, with English assessments generally more aligned than math assessments (Brown & Conley, 2007). Alignment was better in the more basic areas and less so in areas requiring higher cognitive reasoning. For categorical concurrence, although on average across standards, each KSUS English standard was addressed by at least 10 ELA standards in each of the assessments, the number of items masked that, in terms of the frequency with which an assessment met the 6-item benchmark, only 42% of the English assessments met the threshold benchmark, while more than half of the assessments did not have enough ELA items to meet the college-readiness standard (Brown & Conley, 2007). There was poor or no alignment in the areas that required higher order thinking such as critical thinking and research. A similar trend was found in the math assessments, where even though on average across standards, each standard was addressed by at least 11 assessment items, most of the alignment fell within two standards, computation and mathematical reasoning, with glaringly decreasing alignment in sequentially higher math courses (Brown & Conley, 2007). The 6-item benchmark was met for computation in 90% of the assessments; for mathematical reasoning in 93%; for algebra in 63%; for geometry in 60% of the assessments; a plummet in research skills at 3%, and 0% alignment in any of the state assessments for statistics.

For depth of knowledge consistency, more than 60% of the ELA assessment items were at or above the level of cognitive complexity of the corresponding KSUS standard, with alignment most frequent in reasoning and comprehension at 93%; writing at 70% research skills at 66% and critical thinking at 63% (Brown & Conley, 2007). In math, the cognitive complexity alignment was more than 80% in all standards except for trigonometry, which had only 37% alignment (Brown & Conley, 2007).

For the range of knowledge criteria, on average, only 29% of the objectives within the ELA standards were addressed by the assessments, as were 28% in the math standards. In math, less than 13% of the assessments met the benchmark of addressing at least half of the objectives in a given standard (Brown & Conley, 2007).

The average balance of representation index was .63 for ELA, with 79% of the assessments demonstrating adequate balance of representation across all applicable standards, the highest in reading and comprehension at 97%; writing at 83%; critical thinking at 73%; and research skills at 63%. In math, the index was .57 with 75% of the assessments demonstrating balance of representation, with computation, algebra, geometry, and mathematical reasoning showing a high balance of representation at 90% while trigonometry was at 33% representation, and statistics at 0% (Brown & Conley, 2007).

The SAIV index, indicating overall alignment if all subject area assessments were combined, was .507 for the 30 ELA assessments and .509 for the 30 mathematics assessments. The states were more frequently aligned in ELA than in mathematics, with one-third of the states aligned in math and one-half aligned in ELA (Brown & Conley, 2007).

Brown and Conley (2007) suggested that the lack of alignment in trigonometry and statistics resulted from state mathematics assessments being administered in the $10^{th}$ or $11^{th}$ grades prior to students' exposure to the subjects, and some states' election to exclude the subjects from the standards. The study concluded that high school assessments did not cover adequately the areas required for college readiness and, as such, alignment between high school assessments as they then existed, and college-readiness standards, was inadequate to consider substantively as information on the range of knowledge and skills necessary for college readiness (Brown & Conley, 2007).

**Brown and Niemi (2007)**

Whereas Brown and Conley (2007) was a standards-assessment analysis referencing college readiness standards of select research universities across states, Brown and Niemi (2007) investigated alignment between the knowledge and skills required for entry-level courses at California open access community colleges and those measured by the $11^{th}$ grade state assessment. Using the Webb (1997, 1999) methodology, the study was a content analysis of the most commonly used California community college placement assessments and the augmented California Standards Test (CST) which included Algebra II, the Summative High School Mathematics Test, and the Grade 11 ELA Test.

Three analysts with extensive experience conducting content analyses and alignment of curricula, assessments, and standards were trained to conduct the analysis, as described in previous sections. The study was conducted in two phases: content analysis of the placement exams most prevalently used in California community colleges, and alignment ratings analysis of the placement exams along the four criteria of categorical concurrence; DOK consistency; range of knowledge; and balance of representation (Brown & Niemi, 2007). While a review of placement tests in use at CCC showed an array of assessments, the College Board's Accuplacer Computerized Placement Tests and ACT's Compass computer adaptive tests were revealed as the most commonly used. The study also included the Mathematics Diagnostic Testing Program (MDTP) developed by UC and CSU faculty, and the California Test of English Placement (CTEP) developed by community college faculty (Brown & Niemi, 2007).

Seven ELA and 9 mathematics assessments were analyzed. For the computer adaptive tests, reviewers integrated into their content summaries content statements from confidential test specifications and test blueprints provided by the test developers (Brown & Niemi, 2007). Inter-rater reliability checks in math resulted in a 95% level of agreement. The content of the assessments were summarized and organized into category headers and a concise list of content descriptors to simplify the alignment rating process in the second phase (Brown & Niemi, 2007).

For the alignment rating, community college and university faculty with direct experience with high school assessments or teaching community college entry-level courses were recruited. The three alignment rating activities and criteria were as described above in Brown and Conley (2007).

The study found substantial alignment in the categorical concurrence of the augmented CST Grade 11 ELA and the placement exams, but inadequate alignment for math in many content areas. While all ELA content groupings showed sufficient alignment, less than half of mathematics contents groupings were aligned. Some topics on the placement exams did not appear on the CST, primarily lower-level math topics (e.g., whole numbers and fractions) and higher-level topics beyond Algebra II (e.g., trigonometry) (Brown & Niemi, 2007). Sufficient alignment also was found for both ELA and math in depth of knowledge consistency, indicating that the cognitive levels of the augmented CST and placement tests were matched. For range of knowledge, the majority of ELA objectives in each of the placement tests were matched to at least one CST item; however, only 4 in 12 placement test content groupings were sufficiently aligned: algebraic expressions and operations; equations, inequalities, and word problems; and geometry. Consistent with the categorical concurrence findings, several content areas in the math placement tests were not covered by the CST, resulting in weak secondary-postsecondary alignment (Brown & Niemi, 2007). For balance of representation, all of the ELA and math categories met or exceeded the threshold, indicating a balanced distribution across content area objectives. The findings for ELA and math are summarized in Tables16 and 17, respectively.

Table 16

*Summary of the Augmented California Standards Test and California Community College Placement Test Alignment Ratings for English Language Arts*

| Community College Content Area | Categorical Concurrence[a] | Depth of Knowledge[b] | Range of Knowledge[c] | Balance of Representation[d] |
|---|---|---|---|---|
| **Language** | | | | |
| Sentence Structure, Grammar, Syntax, and Usage | 66.60* | 83.55%* | 86.20%* | 0.92* |
| Punctuation | 26.40* | 59.73%* | 100.00%* | 0.99* |
| Rhetorical skills | 15.00* | 49.39% | 100.00%* | 0.92* |
| Organization | 16.60* | 90.78%* | 100.00%* | 0.92* |
| Style | 27.40* | 83.14%* | 100.00%* | 0.93* |
| **Reading** | | | | |
| Vocabulary and Sentence Relationships | 13.80* | 70.71%* | 80.00%* | 0.94* |
| Literal Comprehension | 68.80* | 93.46%* | 91.67%* | 0.82* |
| Main Ideas | 14.60* | 100.00%* | 60.00%* | 0.93* |
| Supporting ideas | 14.60* | 87.23%* | 100.00%* | 0.97* |
| Inferences | 107.00* | 78.83%* | 91.58%* | 0.84* |
| Applications | 14.80* | 92.80%* | 60.00%* | 0.95* |

Source: Brown & Niemi, 2007. Notes: [a] Criterion value for this measure is at least 6.0; [b,c] Criterion value for these measures is at least 50%; [d] Criterion value for this measure is at least 70%; [*]Indicates sufficient values to reflect acceptable alignment.

Table 17

*Summary of the Augmented California Standards Test and California Community College Placement Test Alignment Ratings for Mathematics*

| Community College Content Area | Categorical Concurrence[a] | Depth of Knowledge[b] | Range of Knowledge[c] | Balance of Representation[d] |
|---|---|---|---|---|
| **Mathematics** | | | | |
| Whole Numbers and Fractions | 0.00 | N/A | 0.00% | N/A |
| Decimals and Percents | 0.00 | N/A | 0.00% | N/A |
| Applications and Interpreting Tables/Graphs | 2.75 | 87.50%* | 8.93% | 0.96%* |
| Integers and Rational Numbers | 0.75 | 100.00%* | 12.50% | 1.00* |
| Algebraic Expressions and Operations | 21.00* | 100.00%* | 71.88% | 0.85* |
| Operations with Exponents | 1.75 | 100.00%* | 18.75% | 0.96* |
| Equations, Inequalities, and Word Problems | 12.50* | 89.58%* | 59.09%* | 0.84* |
| Functions | 11.00* | 79.57%* | 58.33%* | 0.78* |
| Trigonometry | 3.75 | 100.00%* | 43.75% | 0.96* |
| Geometry | 14.75* | 87.75%* | 67.19%* | 0.90* |
| Graphing | 4.25 | 100.00%* | 25.00% | 0.96* |
| Applications and Other Algebra Topics | 6.50* | 92.46%* | 26.67% | 0.83* |

Source: Brown & Niemi, 2007. Notes: [a] Criterion value for this measure is at least 6.0; [b,c] Criterion value for these measures is at least 50%; [d] Criterion value for this measure is at least 70%;
[*]Indicates sufficient values to reflect acceptable alignment.

Importantly, Brown and Niemi (2007) pointed out that, of all of the students tested in high school mathematics, relatively few took the Summative High School math Test (5.7%) and the Algebra II test (12.3%), which were the subject of the study, as only students who took the courses were tested in them. Most students took the Algebra I test (40.8%), the Geometry Test (20.8%), or the General Mathematics test (19.6%). Even so, Brown and Niemi (2007) reported considerable overlap among the Summative High School Math, Algebra I, and Geometry tests. All high school students were tested in 11th grade ELA.

The study reported that, not only do only about 18% of students take the two exams each year, but those who do take it have very low passage rates. As Table 18 shows, less than half of the students who took the Summative High School Math assessment in 2006 tested as proficient (46%), while 28% tested at the basic level. One-quarter of the students tested in Algebra II tested as proficient (25%), while 27% tested at the basic level, indicating that nearly half of the students tested below basic (Brown & Niemi, 2007). For the Grade 11 ELA test, 36% tested as proficient and 24% tested at the basic level, leaving two-thirds who tested below basic (Brown & Niemi, 2007).

Table 18

*Statewide Proficiency Rates for California Standards Tests, 2006*

| **CST Test** | **% Basic** | **% Proficient of Above** |
|---|---|---|
| **Mathematics** | | |
| Algebra II | 27 | 25 |
| Summative High School Math | 28 | 46 |
| | | |
| **ELA** | | |
| Grade 11 | 24 | 36 |

Source: Brown and Niemi, 2007

Although there was modest alignment in the content of some of the Summative High School Math and Algebra II test topics and placement exam topics, and strong cognitive alignment, few students took the exam, and fewer students mastered the material covered (Brown & Niemi, 2007). Even in the case of strong alignment as existed between the Grade 11 ELA exam and college placement tests, proficiency on the exam was low, again indicating a lack of content mastery. The researchers thus found it not surprising that large numbers of students are assigned to remediation when they reach the community college (Brown & Niemi, 2007). The findings suggested that, while high school students were taught and tested in content that was moderately to strongly aligned with community college expectations, secondary-postsecondary assessment alignment alone was insufficient to address college remediation, and alignment alone is a necessary but insufficient condition to prepare students to be college-ready (Brown & Niemi, 2007). As Conley and Seburn (2010) pointed out, Brown and Niemi's (2007) findings regarding community college placement tests might not generalize to baccalaureate institutions.

**Shelton and Brown (2008)**

Focusing on the California Standards Tests taken by 81.2% of California 11$^{th}$ grade public high school students, Shelton and Brown (2008) built upon Brown and Niemi's (2007) study and explored the alignment between California community college placement test content and the California Standards Tests for General Mathematics, Algebra I, and Geometry. Complementing the Brown and Niemi (2007) study, which explored the alignment of CCC placement test content and the augmented CST's Grade 11 ELA, Summative High School Math, and Algebra II tests taken by only 18% of California high school students, the two studies together investigated how well community college expectations align with the CST taken by 99.2% of California public school students (Shelton & Brown, 2008).

Shelton and Brown (2008) evaluated the Accuplacer Arithmetic, Elementary Algebra, and college-level math tests; ACT's Compass Numerical Skills/Pre-Algebra, Algebra, College Algebra, and Geometry tests; and MDTP's Algebra Readiness and Elementary Algebra tests (Shelton & Brown, 2008).

Following the modified Webb (1997, 1999) methodology as outlined in the previous studies, the researchers used a purposeful sample of nine subject matter experts, defined as persons qualified and experienced teaching high school or entry-level college mathematics courses, four from high school and five from community colleges in the state (Shelton & Brown, 2008). The experts conducted the rating in a one-day alignment workshop during which they were trained in the purpose of the study, definition of terms and concepts, and the 5-point Marzano (2001) scale used to quantify depth of knowledge (Shelton & Brown, 2008). They then practiced rating depth of knowledge using items from test samples in order to develop a shared understanding of the levels, calibrate concepts of content match and coding, and improve consistency among raters (Shelton & Brown, 2008). Inter-rater reliability, measured by the generalizability coefficient, was calculated for the three tests at .90 for General Mathematics; .84 for Algebra I; and .79 for Geometry, exceeding the .80, .80, and .70 respective minimum thresholds (Shelton & Brown, 2008).

After the training, each rater worked independently and, taking each test separately, compared the items in the CST General Mathematics, Algebra I, and Geometry tests to the placement test objectives in a two-step process (Shelton & Brown, 2008). Raters individually evaluated alignment along four criteria: 1) categorical concurrence; 2) depth of knowledge consistency; 3) range of knowledge; and 4) balance of representation. Categorical concurrence was a binary “meets” or “fails to meet” rating and was met when at least six assessment items address a standard’s objective (Shelton & Brown, 2008). Depth of knowledge classified cognitive complexity using Marzano’s (2001) categories of retrieval, comprehension, analysis, knowledge utilization, and metacognitive processes, and was rated along a 1-5 scale (Shelton & Brown, 2008). Depth of knowledge consistency was reached when at least half of the items matched to a standard were rated at a cognitive level at least equal to the standard’s level of cognitive complexity (Shelton & Brown, 2008). The range of knowledge criterion required that at least half of the standard’s objectives are mapped to at least one question, resulting in a minimum ROK value of .5 (Shelton & Brown, 2008). An assessment item had balance of representation when it was distributed evenly among objectives. The threshold for balance of representation was .70 (Shelton & Brown, 2008).

Shelton and Brown (2008) found “areas of gross inconsistency” and areas of adequate alignment between the community college placement standards and the CST (p. 12). The study determined adequate alignment between the CST and two-thirds of the categories of placement test objectives, and poor alignment in one-third of the categories (Shelton & Brown, 2008). Algebra I matched the standards in two areas only: algebraic expressions and operations. Geometry matched only in Geometry; and General Mathematics matched across most standards (Shelton & Brown, 2008). The CST did not test four out of twelve of the placement test standards categories: namely, integers and rationals, functions, trigonometry, and graphing (Shelton & Brown, 2008). Several items had categorical concurrence (were mapped to a minimum number of a standard’s objectives) but not range of knowledge, suggesting that many of the standards that had a content match emphasized objectives that were not on the tests (Shelton & Brown, 2008). In the content categories that did match, cognitive levels also matched favorably (Shelton & Brown, 2008).

## Issues and Limitations

Webb (2007) discussed five criteria-related issues specific to the Webb (1997, 1999) alignment model. The question underlying each issue pertains to the adequacy of the established levels of alignment; that is, "when an alignment is good enough" (Webb, 2007, p. 24). Acceptable levels were established based on assumptions about what a passing score should be; the number of items required to make decisions on student learning; and the number of items that can be included in an assessment, all of which could vary depending on the purpose of the assessment (Webb, 2007). None of the issues Webb (2007) raised are resolved.

### Categorical Concurrence

The criterion provides an indication of whether both documents under review include the same content alignment for this criterion assumes that six is an acceptable number of assessment items mapped to one objective. The number was estimated based on a procedure developed by Subkoviak (1998) that estimated six as the number of items that would produce a minimum agreement coefficient of .63 for judging mastery based on assessments (Webb, 2007). The alignment allows variation of the number used to define an acceptable level.

### Depth of Knowledge

The setting of 50% as an acceptable level for DOK alignment is based on the assumption that minimum proficiency is scoring 50% of items correct and that at least half of the items on an assessment should be at the same or higher level of knowledge complexity as the related content objective (Webb, 2007). The level of acceptability, however, should have some bearing on the purpose of the assessment. All or most of the items should be at the same level if the purpose of the assessment is to make a dichotomous determination of proficient versus not proficient. In this scenario, the decision rule is based on the binary proficiency judgment. In contrast, there should be a range of DOK levels with some items below, at, or above the cognitive level of the corresponding objective if the purpose of the assessment is to place students along a range of proficiency levels (Webb, 2007). In this scenario, the decision rule could be based on the range of complexity.

**Range of Knowledge Consistency**

The 50% level of acceptability for range of knowledge is impacted by several factors, including the length of the assessment; the number of objectives; the breadth of content a standard covers; and different levels of importance of a standard's objectives. An assessment with few items and standards with large numbers of objectives can be difficult to assess (Webb, 2007).

**Balance of Representation**

The balance of representation level of acceptability assumes that assessment items should be relatively equally distributed among objectives under a standard even though it is reasonable that some standards or some objectives under a standard might have more importance than others (Webb, 2007). An underlying issue is the extent to which emphasis placed on a standard's objectives should vary. Depending on differences in emphasis, a lower index could be acceptable (Webb, 2007).

**Changes in Depth of Knowledge Levels Across Grades**

As students progress from grade to grade, it is reasonable to assume that the level of cognitive complexity increases; however, the methodology has no guidelines on an acceptable progression of content cognitive complexity across grades (Webb, 2007). Shelton and Brown (2008) reported that Marzano's (2001) scale addresses the sequential levels of cognition; thus, the researchers modified Webb's (1997, 1999) methodology by using the first 5 levels of the Marzano scale to rate depth of knowledge consistency. The current study adopts the modification but uses only the first 4 levels of the Marzano scale. The fifth level relates more to the habits of mind outlined in the Common Core's practice standards as opposed to its content standards.

Bhola et al. (2003) listed three categories of problems in aligning tests regardless of the model used: 1) specificity of alignment criteria; 2) classifying students into performance categories; and 3) training of the subject matter expert raters. Any or all of these issues can affect the meaning and efficacy of the alignment study.

**Specificity**

Some standards are multi-dimensional, whereas the content of the assessment items aligned to it emphasize only one dimension (Bhola et al., 2003). For example, a standard that relates to five different types of numeric representations and a test item that relates to only one of the five would be considered aligned in terms of content, as would any combination of the five representations on a test item (Bhola et al., 2003). Alignment is more easily determined when the standards and assessment items are written to a similar level of specificity with a clearly-defined rubric (Bhola et al., 2003). Webb (1997) suggested that the goal is to align assessments with general standards as opposed to more specific objectives.

**Student Performance Categories**

Classifying students into performance categories based on proficiency levels can be problematic when classification beyond dichotomous decisions (e.g., proficient or non-proficient) involving more than two performance categories are required, as with Title I (Bhola et al., 2003). For each performance category, related items must be added throughout the assessment for all levels of proficiency to allow students at all ability levels the opportunity to demonstrate their proficiency (Bhola et al., 2003). Not only must there be a sufficient number of assessment items, but there also must be enough items along the range of skill levels (Bhola et al., 2003). La Marca (2001) addressed this issue through alignment of the accessibility criterion but did not specify how many items must be aligned in order to be classified into more than one performance category (Bhola et al., 2003). Webb (1999) suggested that at least six assessment items must relate to a standard to be classified into more than one performance category (Bhola et al., 2003).

**Training of Expert Reviewers**

Bhola et al. (2003) emphasized the importance of through training as an essential element of the alignment process. Reviewers are likely to include teachers familiar with the students, standards, and curriculum, who might be inclined to stretch the definition of a match in order to ensure that every item has a match to avoid any semblance of failure. Reviewers who expand content match decisions to include indirect measures can make irrelevant matches. Employing the generalizability coefficient to ensure inter-rater reliability can address this issue. Bhola et al. also cited the difficulty in obtaining high-quality test questions, as practice items tend to be simpler than the actual test.

## Summary

The literature review supported the current study's purpose to evaluate the extent to which the California Common Core Content Standards for Higher Mathematics (9-12) align with the California State University system's Entry-Level Mathematics placement assessment. Alignment is important as it informs instruction and classroom activity (teaching/learning activity), shown to be the most important factor in student achievement (Biggs, 1996; Hess et al., 2009). Empirical studies indicated that instruction aligned with standards and assessments has up to a four-fold effect on student learning; the potential to close achievement gaps; and facilitates lower-achieving students performing at a higher cognitive level.

California's public school system provided the context for the study, as the state recently implemented the K-12 Common Core State Standards and is piloting assessments developed by the Smarter Balanced Assessment Consortium (CCSSI, n.d.). Studies on the Common Core are nascent. Studies on the Entry Level Mathematics placement test, used in the California State University system, the largest baccalaureate system in the world, are rare and largely unpublished. The current study was intended to help fill the gap in this research.

Low-, moderate-, and high-complexity alignment analysis models were reviewed and the high-complexity Webb (1997, 1999) methodology was selected for the current study. The study builds upon and extends the curricular alignment work of Conley et al. (2011), Brown and Conley (2007), Brown and Niemi (2007), and Shelton and Brown (2008) that variously benchmarked the Common Core standards against other standards, and investigated the alignment of California community college placement assessments and high school exit-level standards. Details of the methodology are set forth in the next chapter.

# CHAPTER 3: METHODOLOGY

This chapter outlines the methodology used to study the alignment between secondary math standards and entry-level college math placement assessments. The chapter reviews the study's purpose, research design, participants, instrumentation, procedures, data analysis, limitations, and summary.

## Purpose of the Study

The purpose of this study was to determine the extent to which the California Common Core Content Standards for Higher Mathematics (9-12) were aligned with the California State University system's Entry-Level Mathematics placement assessment. The study followed the curricular alignment work of Conley et al. (2011), Brown and Conley (2007), Brown and Niemi (2007), and Shelton and Brown (2008) that variously benchmarked the Common Core standards against other standards, and investigated the alignment of California community college placement assessments and high school exit-level standards. Not well examined to date are the placement assessments used in California public 4-year universities.

## Research Design

The study used a mixed research design, incorporating a quantitative, non-experimental, psychometric content analysis and qualitative subject matter expert judgment to determine whether the Common Core math standards and the ELM placement test encompass similar content topics in the same breadth and depth within an established knowledge organizational framework. A quantitative methodology used pre-developed design and objective measurement to arrive at findings that are systematic, generalizable, and replicable by other investigators, using preselected instruments and statistical analysis of numeric data.

Federal law has required the alignment of standards and assessments since the passage of the 1994 federal Title I legislation, and 2002 NCLB legislation requires states to develop standards-aligned assessments (Webb, Herman, & Webb, 2006). Systematic alignment assessment procedures have been well-developed by pioneers Andrew Porter and Norman Webb (Bhola et al., 2003, Webb et al., 2006). The research design followed Webb's (1997, 1999, 2002) standards-to-assessment alignment protocol which convenes a panel of expert reviewers to analyze assessment items against content standards by level of cognitive demand (Webb et al., 2006). The study incorporated quantified coding and qualitative expert judgment to yield alignment statistics across five criteria: 1) categorical concurrence; 2) depth of knowledge correspondence; 3) range of knowledge consistency; 4) balance of representation; and 5) source of challenge.

## Research Questions

The overarching research question was: To what extent will successful completion of mathematics courses as prescribed by the California Common Core Content Standards for Higher Mathematics (9-12) lead to mastery of the skills required for college-level math placement as determined by the California State University Entry-Level Mathematics placement test? The following specific research questions guided the study:

1. To what extent are the California Common Core Content Standards for Higher Mathematics (9-12) aligned with the California State University Entry-Level Mathematics placement test?

2. What cognitive demands are emphasized in the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University Entry-Level Mathematics placement test, respectively?

3. What is the alignment between the breadth of knowledge of the standards and the assessment?

## Participants

Participants in the WAT-supported alignment study included a program administrator (the researcher), an expert sampling of subject matter reviewers, and a group leader selected from among the reviewers (Webb, Alt, Ely, & Vesperman, 2005). Each had distinct roles and responsibilities in the study.

Prior to the alignment event, the program administrator was responsible to organize the study, including registering the group and type of study online at the WAT website; securing a group identification number and providing access to the site to the reviewers; entering information about the assessment; entering the state standards; creating the study by pairing the assessment and the standards; securing the technology-equipped location to conduct the study; and related administrative and organizational matters (Webb et al., 2005).

The group leader was responsible to train the reviewers on the subject matter content's depth of knowledge levels (Phase I); instruct the reviewers how to register on the WAT site for the alignment group; facilitate the DOK group consensus process; train the reviewers how to code the assessment items (Phase II); enter the group DOK values of the objectives; and lead a debriefing process (Webb et al., 2005).

Reviewers were charged to participate in the training; assign a DOK value to each of the standards and objectives; discuss in a group leader-led interchange with other reviewers how the DOK level was coded, and reach consensus on any differing DOK levels; code the assessment items; and debrief in a group interview with the group leader (Webb et al., 2005). A downloadable training manual was provided online with detailed, step-by-step instructions for each of these responsibilities for each role.

**Recruitment**

This study recruited six subject matter experts from California high schools, community colleges, and universities to serve as alignment reviewers. Subject matter experts were defined as high school and higher education educators with direct experience teaching high school, remedial or entry-level college math courses, and secondary and postsecondary instructional officers with educational reform and assessment experience. All were familiar with the Common Core Content Standards for Higher Mathematics (9-12). Webb, Alt, Ely, Cormier, and Vesperman (2005) suggested that objectivity is enhanced with a combination of internal (within-state) and external (out-of-state) reviewers. Although out-of-state participants were invited to participate, none were available during the time frame the study was conducted.

Recruitment of the expert sample was accomplished using multiple methods, including a nomination process and snowball sampling. The researcher recruited and requested nominations from a nationally recognized university mathematics professor and co-author of mathematics textbooks, the *Draft California Mathematics Curriculum Framework*, and the Intersegmental Committee of the Academic Senates Subcommittee on the Mathematics Competency's *Statement of Competencies in Mathematics Expected of Incoming College Students*. The researcher contacted nominees by telephone and email, requested their participation and additional nominations. The researcher also recruited from members of an intersegmental California Central Valley university enrollment advisory committee comprised of secondary and postsecondary instructors and educational leaders who meet quarterly to address college readiness and remediation issues. (It is from this group that the original research question emanated.) Participants were selected purposively from these groups. The university math professor served as group leader.

Potential participants were informed that their identities and affiliated schools would not be kept confidential, as reviewer expertise was key to the validity and credibility of the study. They were advised that they would be a part of a panel of reviewers; asked to commit four to six hours (given the number of standards and objectives) to participate in a standards-assessment alignment analysis; and informed that they could withdraw from the study at any time. As incentive to participate, in addition to the opportunity to contribute to a study that could have implications on the assessment being developed by Smarter Balance and on the future direction of the CSU's math placement assessment instrument, participants were offered a $250 gratuity for their time.

## Instrumentation

Quantitative data were collected using the WAT, an internet application that automates the process of evaluating the alignment between state standards and standardized assessments along the five criteria in the Webb (1997, 1999) alignment assessment protocol (Webb, Alt, Ely, & Vesperman, 2005). The tool collected data in separate standards-assessment matrices by content and cognitive demand. Qualitative data were collected using a post-assessment debriefing questionnaire.

**The Webb Alignment Analysis Protocol**

The quantitative instrumentation for this alignment research was the Webb alignment analysis protocol, a high complexity alignment model (Bhola et al., 2003) that relies on the judgments of multiple expert raters to match a large number of objectives to assessment items. The reviewers first coded the cognitive level of the standards and objectives, reached consensus on those levels, then coded the assessment items, and identified objectives that were targeted by the assessment items, if any. The results were converted into quantitative data and analyzed. Following are Webb's (1997, 1999) five alignment criteria:

- Categorical Concurrence measures the degree to which the same or consistent content topics appear in the standards and assessment. To meet the criterion, each standard must be mapped to a minimum of six assessment items (Webb, Alt, Ely, & Vesperman, 2005).
- Depth-of-Knowledge consistency measures the degree to which the cognitive demands of the standards match those of the assessment. The criterion is met if a minimum of 50% of the assessment items mapped to a standard are at the same cognitive level as the standard. The study used the first four levels of the Marzano scale of cognitive demand to measure DOK :
    - Level 1 –Retrieval;
    - Level 2 – Comprehension;
    - Level 3 – Analysis; and
    - Level 4 – Utilization (Brown & Conley, 2007).
- Range of Knowledge Correspondence measures whether the standards and assessment encompass a comparable span of knowledge. The

criterion requires that at least 50% of the standards are linked to at least one assessment item.

- Balance of Representation measures whether content topics are given the same emphasis in the standards and assessment. The criterion requires that most of the objectives are being measured by a comparable number of assessment items and is met when the balance is at least .07 (Webb, Alt, Ely, & Vesperman, 2005).
- Source of Challenge identifies knowledge required to achieve the standard that is unrelated to the standard (e.g., cultural bias or the level of reading required to complete a math problem) (D'Agostino et al., 2008; Webb, Alt, Ely, & Vesperman, 2005).

The WAT, accessible at http://wat.wceruw.org/index.aspx, substantially reduced the time and labor intensity of the alignment process. Figure 17 is a screenshot of a sample reading assessment item coded to a standard along the depth of knowledge and source of challenge criteria. The page shows that a reviewer coded Reading Item 15 at a Depth of Knowledge (DOK) Level 1 and mapped the assessment item to Standard CS1.3. If the reviewer determined the items did not match, the reviewer would check the "uncodable" box. There is space to identify secondary objectives identified with the standard as well as space to provide qualitative data on any source of challenge for the standard, and additional comments. The reviewer easily can toggle forward to Reading Item 16, backward to review Reading Item 14, print out a summary table of the data entered to that point, or receive a reminder of the coding for the current criteria. In comparison, Table 19 is an example of a paper version of the coding sheet with the same information.

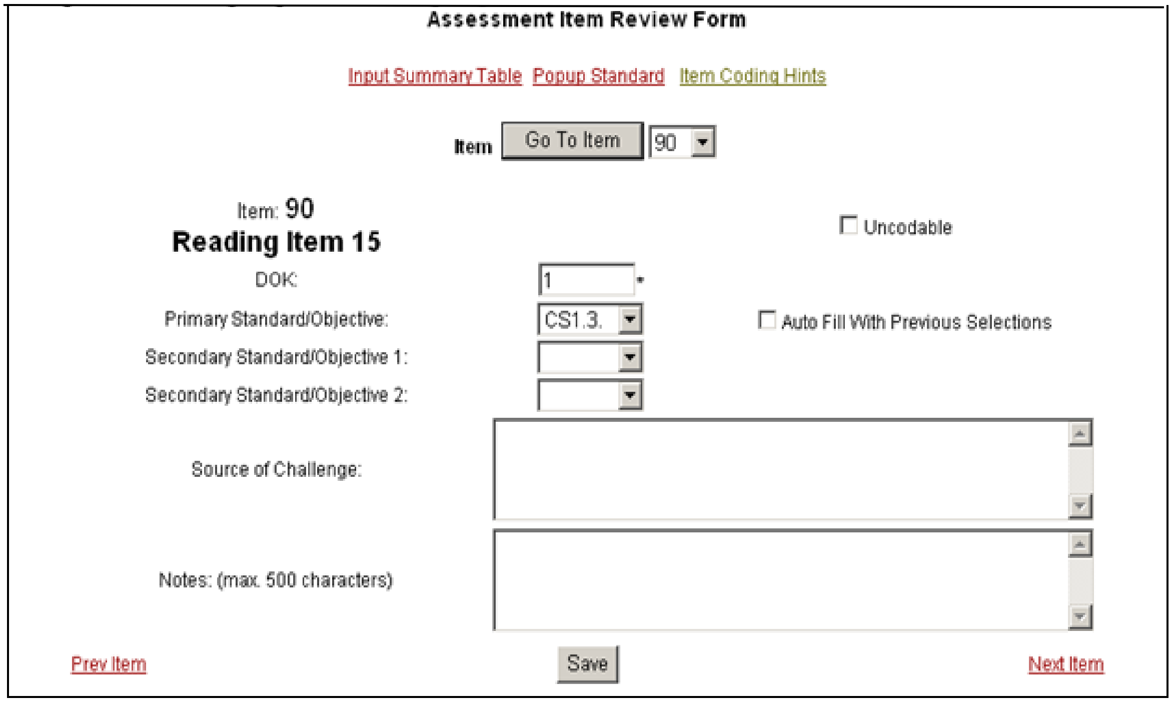


*Figure 17*. Online assessment item review form with sample reading assessment coding to a standard. Source: Webb, Alt, Ely, & Vesperman, 2005, p. 41.

Table 19

*Assessment Coding Sheet Example*

| Coding Form State | | Reviewer | | | Date | |
|---|---|---|---|---|---|---|
| Content Area: | | Grade: | | Test Form: | | |
| Item Number | Item DOK | Primary Objective | Secondary Objective | Secondary Objective | Source of Challenge | Notes |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| … | | | | | | |
| 15 | 1 | CS1.3 | -- | -- | -- | -- |

Source: Webb et al., 2005, p. 99.

Similarly, Figure 18 is a screenshot of a reviewer's Depth of Knowledge coding of a math standard. The page shows that for Standard 1, Numbers and operations, the reviewer mapped Objectives 1.a, 1.b, and 1.c at Depth of Knowledge levels 2, 1, and 1, respectively.

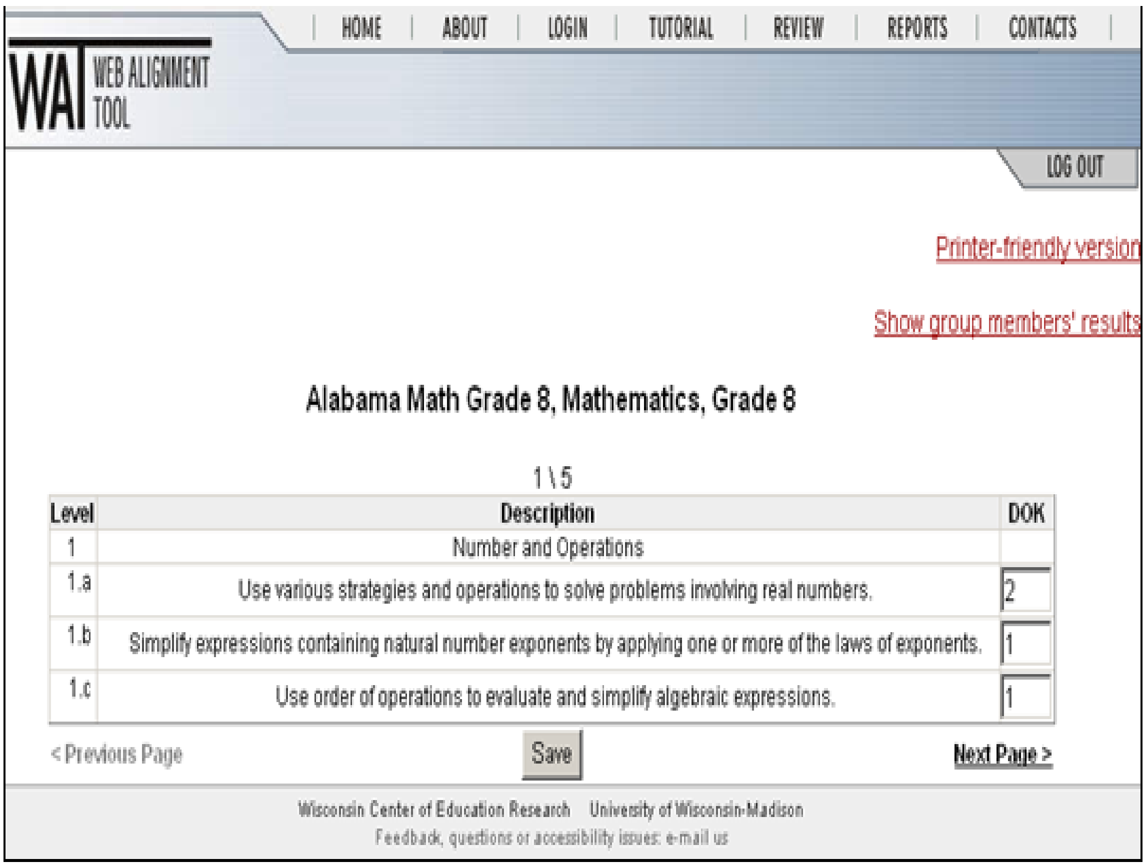


*Figure 18*. Sample depth of knowledge coding for a math standard. Source: Webb, Alt, Ely, & Vesperman, 2005, p. 39.

Prior to the expert reviewer ratings, the on-line study was set up by the program administrator (the researcher) who populated the fields with the assessment items and the standards to be analyzed.

**Debriefing questionnaire**. The consensus process was an abbreviated, quasi-professional learning community (PLC) that allowed high school and higher education math experts to engage and share perspectives regarding the placement assessment, the standards, and their rationale for making assigning DOK levels and identifying matching objectives. The Source of Challenge and Notes sections on the assessment item coding pages allowed reviewers to share additional insights (see Figure 17). Finally, qualitative data were collected using a post-assessment debriefing questionnaire. The protocol suggested the following questions to guide the group interview:

1. For each competency, did the items cover the most important topics you expected on the competency? If not, what competency was not appropriately covered and what topics were not assessed that should have been?

2. For each competency, did the items cover the most important performance (DOK levels) you expected on the competency? If not, what competency was not assessed at an appropriate depth-of-knowledge level and how should the assessment of the competency be improved?

3. Compared to competencies and assessments in other grades, did the competencies and assessment at this grade show an appropriate progression in content and depth of knowledge?

4. What is your general opinion of the alignment between the competencies and assessment?

    a. Perfect alignment
    b. Acceptable alignment
    c. Needs slight improvement
    d. Needs major improvement
    e. Not aligned in any way?

5. Other comments?

## Instrument Reliability

Instrument reliability was analyzed from 2003 to 2005 using data collected in 34 alignment studies, during which the online assessment tool was developed and refined (Webb, Alt, Ely, Cormier, et al., 2005). The studies were selected to assess the alignment method's reliability because they covered a range of content domains including mathematics, language arts, science, and social science; standards and assessments; a range of grades 2-12; a range of three to nine reviewers, and sets of standards ranging from four to 77 objectives (Webb, Alt, Ely, Cormier, et al, 2005). Since the instrument relies on the participants' entry of data regarding the DOK levels of the standards and assessment item, as well as which objectives are covered by each assessment item, the reliability of the instrument depends on the reliability of the data entered (Webb, Alt, Ely, Cormier, et al., 2005). Central to the issue of reliability is the reliability of the four alignment criteria.

Webb, Alt, Ely, Cormier, et al. (2005) noted that the reliability of the participant consensus process by which the DOK levels of the standards and assessment items are determined was not assessed by experimental analysis (e.g., comparison of randomly assigned groups' coding of the same standards). DOK reliability was assessed by evaluating the within-group consistency of assignment of DOK levels which entailed comparing the DOK levels of the assessment items and standards (Webb, Alt, Ely, Cormier, et al., 2005). DOK data were analyzed using intraclass correlation, which measures the percent of variance in the data between assessment items as opposed to variances in the data between reviewers (Webb, Alt, Ely, Cormier, et al., 2005). An intraclass correlation value of .7 or greater is considered adequate and indicates that 70% of the variance in the data can be attributed to differences in the assessment items and 30% to differences between the reviewers. A value of .8 or higher is considered good. When item variance is low, the pairwise agreement statistic is the preferred reliability measure. Pairwise agreement is measured by determining, for every possible pair of raters, whether the pair coded items identically. A pairwise agreement value of .5 or less indicates poor agreement; .6 or higher indicates adequate agreement; and .7 or higher indicates good agreement (Webb, Alt, Ely, Cormier, et al., 2005; Webb, Alt, Ely, & Vesperman, 2005).

Of the 34 alignment studies analyzed, DOK reliability exceeded the .7 threshold for intraclass correlation in 30 studies. Two of the studies had a small number of reviewers. Reliability increases as the number of reviewers increases, is optimized with eight or more reviewers, and is lowered with three or fewer reviewers (Webb, Alt, Ely, Cormier, et al., 2005). In the two remaining studies, variance between the assessment items was low; thus, the pairwise agreement value was calculated, which exceeded the .6 threshold. DOK reliability was adequate in 94% of the studies analyzed (Webb, Alt, Ely, Cormier, et al., 2005).

The categorical concurrence criterion is met if at least six assessment items are linked to a standard. Reliability of the criterion requires reliability of the coding at the standards level. The standard pairwise comparison statistic exceeded the .5 threshold in all except 11% of the 34 alignment studies; thus, the criterion is deemed reliable (Webb, Alt, Ely, Cormier, et al., 2005).

The range of knowledge criterion is met if at least half of the standards are mapped to an assessment item. Reliability of the criterion depends on reliability of the coding of the objective. A study with an objective pairwise comparison value of .5 calculated a Range of Knowledge error value of $\leq .1$ (Webb, Alt, Ely, Cormier, et al., 2005).

The balance of representation criterion is met when assessment items linked to a standard are evenly distributed across the standard's objectives. Reliability of the balance of representation criterion is dependent on the coding of the objectives and the standards (Webb, Alt, Ely, Cormier, et al., 2005).

**Procedures**

The Fresno State Institutional Review Board approved the research as exempt from human subjects research certification.

A purposive sample of six high school and college entry-level mathematics experts were recruited to analyze and code the standards and assessment items along established common criteria. Each reviewer was provided a copy of the standards, assessment, scoring rubric, definitions of the alignment criteria and depth of knowledge levels, test non-disclosure forms, and alignment instructions. The CA CCSSM (9-12) are arranged conceptually into five categories with 192 ratable statements:

- Number and Quantity (32): 27 standards and 5 sub-standards
- Algebra (34): 27 standards and 7 sub-standards
- Functions (45): 28 standards and 17 sub-standards
- Geometry (45): 43 standards and 2 sub-standards; and
- Statistics and Probability (36): 31 standards and 5 sub-standards.

Together, the researcher and group leader trained each reviewer individually and asynchronously by telephone. Training included introduction to the alignment protocol and online assessment system, orientation to the purpose of the study, a review of definitions, ratings criteria and scales, and sample assessment items to develop a shared understanding of the DOK levels.

After training, the raters conducted the two-step alignment process. First, each rater independently determined the depth of knowledge of the objectives.

Once all of the reviewers completed their independent DOK ratings, the group leader facilitated discussions with the reviewers by telephone, during which they discussed ratings that did not have perfect agreement, identified and discussed differences, and reached consensus on decision rules and the DOK levels. Next, using the consensus DOK levels of the objectives, each rater individually assigned a DOK rating to each of the ELM assessment items. They identified the primary objective and no more than two secondary objectives (sub-standards) that each assessment item fully matched. They also identified any source of challenge (Figure 17). The ELM consists of 50 multiple choice questions, 45 of which are scored, and five of which are field-tested for future use. Per the protocol, the five field-test items were not reviewed. The ELM content is 35% Numbers and Data; 35% Algebra; and 30% Geometry. After completing the coding, each reviewer answered a brief 5-question written debriefing survey.

**Data Analysis**

The WAT computed the number of “hits” by standard (assessment-standards matches coded along the five criteria), to produce statistical tables to analyze and interpret a variety of data. The four principal alignment data tables that were analyzed pertain to content match (categorical concurrence); depth (depth of knowledge consistency); and breadth (range of knowledge correspondence and balance of representation). In addition to the statistical tables, a descriptive summary showing alignment strengths and weaknesses with “yes,” “no,” or “weak” alignment descriptors was generated for at-a-glance analysis to guide further areas of inquiry and analysis.

Data collected was used to facilitate analyses and provide a descriptive summary, including:

- The percentage of objectives by DOK level;

- The percentage of assessment items by DOK level;
- Standards or objectives by DOK level;
    - Which standards or objectives are matched to low cognitive demand levels? High cognitive demand levels?
- Assessments corresponding to the objectives as matched by the number of reviewers;
- Standards not linked to assessment items, and vice versa (uncodable);
- Over- or under-emphasis of any of the standards;
    - The cognitive impact of adding an item to the ELM to address a currently unmatched objective to improve alignment;
    - The impact of shifting standards to improve balance of representation;
- Qualitative descriptions of weaknesses in any of the criteria
- Sources of challenge identified by multiple reviewers
- Inter-rater reliability (intraclass correlations and pairwise agreement).

## Limitations

Reviewer qualifications and training adequacy are limitations to the validity of the coding. The number of reviewers can lower the reliability of the scores. The inclusion of an external rater can reduce rater bias that could result from using only internal reviewers. Webb, Alt, Ely, Cormier, et al. (2005) and Webb, Alt, Ely, and Vesperman (2005) informed that a minimum of six reviewers is required to achieve reliability; eight reviewers are optimal; and, while it might be convenient to have fewer than seven reviewers, fewer reviewers compromise reliability of the coding. The current study recruited eight reviewers; however, only six were available to participate during the given time frame. No external reviewers were available to participate during the time frame of the study. With the large number of objectives in the CA CCSSM (9-12), reviewer fatigue can be a limitation, as can technology issues with the on-line assessment tool.

## Summary

The chapter detailed the Webb (1997, 1999) alignment methodology selected to examine the alignment between the Common Core math standards for higher mathematics and the CSU's ELM placement test. Math experts were recruited by expert sample to analyze the alignment. Quantitative data were collected along specified criteria using an online assessment tool. Source of challenge, reviewer notes, and a post-analysis debriefing survey were used to collect qualitative data. Issues and limitations of the protocol were identified. The participation of at least six reviewers and thorough reviewer training were paramount to ensure coding reliability.

# CHAPTER 4: RESULTS/OUTCOMES

The purpose of this study was to determine the extent to which the California Common Core Content Standards for Higher Mathematics (9-12) were aligned with the California State University system's Entry-Level Mathematics placement assessment. The study examined the alignment between high school's and higher education's expectations of what students should know and be able to do to be considered ready to enroll and succeed in an entry-level college mathematics course without remediation. The study also was intended to serve as a validity study of the rarely-examined CSU mathematics placement assessment. This chapter reports the key findings regarding the extent of the alignment between the CA-CCSSM (9-12) and the CSU ELM placement assessment based on the judgment of a panel of mathematics experts using an accepted alignment analysis methodology.

## Review of the Methodology

The study employed a mixed-methods research design, integrating a quantitative, non-experimental, psychometric content analysis, qualitative subject matter expert judgment, and an open-ended debriefing survey. The research design adapted Webb's (1997, 1999, 2002) high-complexity standards-to-assessment alignment analysis model to identify content topics and levels of cognitive demand for each objective and assessment item to reveal degrees of consistency between the documents.

### The Mathematics Alignment Reviewers

Using nomination and snowball processes, the study convened a purposive sample of California higher education faculty and high school instructors who were subject matter experts experienced in K-12 standards, reform, and/or assessment issues. Three reviewers were from the high school level, one was from the community college level, and two were from a 4-year public university. All reviewers were internal and no external reviewer (outside of California) participated. Experience and expertise of the high school content reviewers included, but was not limited to participation on the California Curriculum Framework Committee, the committee to develop the SAT math subject test and district-level standards, and district-level Common Core mathematics resource instruction. Expertise and experience of the higher education content experts included co-authorship of the *Draft California Mathematics Curriculum Framework*, the Intersegmental Committee of the Academic Senates Subcommittee on the Mathematics Competency's *Statement of Competencies in Mathematics Expected of Incoming College Students*, multiple math textbooks, teacher and student solutions manuals, pre-service teacher education, and Beginning Teacher Support and Assessment (BTSA) content expertise. A list of reviewers is provided in Table 20 and their curricula vitae are provided in Appendix B.

The reviewers conducted the analysis asynchronously at their convenience within a set time frame. Each was trained by phone in the purpose of the study, definitions, criteria, rating scales, and the analysis protocol. In accordance with the protocol, reviewers individually coded the depth of knowledge levels of the objectives in the standards; collectively reached consensus on the DOK levels; individually judged the DOK levels of the assessment items; individually identified objectives that were targeted by each assessment item (if any), and individually answered the debriefing questions. The expert judgments were coded, aggregated, and analyzed for commonalities and differences along the alignment criteria.

Table 20

*Alignment Analysis Reviewers*

| Name | Level | Position | Affiliation | State |
|---|---|---|---|---|
| Kyle Atkin | High School | Resource Teacher | High School District Office | CA |
| Terran Felter | Higher Education | Developmental Math Program Coordinator and Sole Instructor | 4-year Public University | CA |
| Joseph Fiedler | Higher Education | Pure Mathematics Instructor; Curriculum Framework, Statement of Competencies; co-author of textbooks | 4-year Public University | CA |
| Andy Hicks | High School | Algebra II, Geometry Instructor; Common Core Resource Specialist | High School | CA |
| Brian Shay | High School | Algebra I, II… Instructor, Curriculum Framework | High School | CA |
| Bruce Yoshiwara | Community College | Mathematics Professor Emeritus; co-author of textbooks | Community College | CA |

**The California Common Core Content Standards**

**for Higher Mathematics (9-12)**

The CA CCSSM (9-12) are organized into five conceptual categories, 54 standards, and 192 ratable objectives, as follows:

- Number and Quantity (32): 27 standards and five sub-standards
- Algebra (34): 27 standards and seven sub-standards
- Functions (45): 28 standards and 17 sub-standards
- Geometry (45): 43 standards and two sub-standards; and
- Statistics and Probability (36): 31 standards and five sub-standards.

**The CSU Entry-Level Mathematics Placement**

**Assessment**

The CSU ELM placement test studied in this analysis was provided by ETS with the permission of the CSU CO. As with all ELM placement assessments the test used in the current study contained 50 assessment items, five of which were field-test items. Field test items are not counted in student scores; thus, were excluded from the current study. All of the 45 assessment items reviewed were weighted equally. The ELM placement test content was 35% Numbers and Data; 35% Algebra; and 30% Geometry.

**Alignment Criteria**

Reviewers analyzed the alignment between the standards and assessment items against five alignment metrics: 1) categorical concurrence; 2) depth of knowledge correspondence (DOK); 3) range of knowledge consistency; 4) balance of representation; and 5) source of challenge. The DOK levels were rated using the Marzano (2001) scale of progressively higher cognitive complexity:

Level 1 (retrieval);

Level 2 (comprehension);

Level 3 (analysis); and

Level 4 (knowledge utilization).

Reviewer notes and post-analysis open-ended debriefing questions were used to illuminate the quantitative data. Reviewers recorded their judgments using the WAT, an online data-collection software program that compiled the data, calculated the results, and generated reports on the alignment criteria.

The Webb protocol established benchmarks for acceptable levels of alignment for each criterion. For categorical concurrence, alignment was reached if at least six assessment items were judged as targeting a standard. The alignment benchmark for DOK consistency was .5 and was considered weak at a level of .4. Breadth of coverage had two indicators and was rated by range of knowledge and balance of representation, considered aligned at .5 and .7, respectively. Range of knowledge was considered weakly aligned at .4, and balance of representation was weakly aligned at 0.6. The benchmarks for the alignment criteria are summarized in Table 21.

Table 21

*Alignment Levels of Webb's (2005) Alignment Criteria*

| Alignment Level | Categorical Concurrence | Depth of Knowledge | Range of Knowledge | Balance of Representation |
|---|---|---|---|---|
| Acceptable | 6 or more test items per standard | 50% or greater | 50% or greater | .7 |
| Weak | --- | 40-49% | 40-49% | .60-69 |
| Unacceptable | Less than 6 test items per standard | Less than 40% | Less than 40% | Less than .6 |

Note: Weak alignment indicates that the value was within 10% of the criterion threshold, or within 0.1 for the balance of representation criterion (Webb, Wise, & Tindal, 2005).

**Inter-Rater Reliability**

When expert judgment is used to evaluate alignment, the reliability of reviewer ratings is vital. Reliability of reviewer judgments was addressed by assessing two reliability indices. An intraclass correlation coefficient was calculated to assess the reliability of the DOK coding of the assessment items, and pairwise agreement was employed to measure the reliability of the DOK coding of the standards to the assessment items.

**Intraclass correlation for DOK coding of assessment items**. Intraclass correlation values indicate the degree of agreement between reviewers (Webb, Alt, Ely, Cormier, et al., 2005; Webb, Alt, Ely, & Vesperman, 2005). Shrout and

Fleiss's (1979) method of calculating intraclass correlation was employed using their "fixed judge effects" (p. 422) case. The measurement indicates the percent of variance in the data that is due to the difference in the assessment items and the percent of variance in the data that is due to the difference between reviewers (Webb, Alt, Ely, Cormier, et al., 2005; Webb et al. 2006). In the Shrout and Fleiss (1979) model, when a fixed set of several judges rate the same targets, as in the current study, individual judge's ratings are evaluated, then pooled, and the pooled rating is treated as a fixed effect. Any variability among the reviewers will have no effect on the data. Any difference in the data thus can be attributed to variability in the items, as opposed to variability among the raters. The calculation is:

$$ICC = \frac{\sigma^2(i)}{\sigma^2(i) + \sigma^2(r)}$$

where $\sigma^2$ is the item variance and $\sigma^2$(r) is the inter-judge variance (Shrout & Fleiss, 1979). A value above .7 indicates that 70% of the variance can be attributed to variance between the assessment items and 30% to variance among the reviewers. The benchmark for adequate intraclass correlation is a value above .7. A value above .8 is considered good (Webb, Alt, Ely, Cormier, et al.; Webb, Alt, Ely, & Vesperman, 2005; Webb et al., 2006). As shown in Appendix C, the Depth-of-Knowledge Levels by Item and Reviewers; Intraclass Correlation Report, the intraclass correlation statistic for the current study was calculated at .754, meeting the benchmark for adequate intraclass correlation and indicating an acceptable percentage of variance among reviewers' depth-of-knowledge ratings.

**Pairwise agreement for DOK coding of objectives**. It is important to note that the standard-assessment matches were *coded* at the objectives level, the level that most specified the activities or skills students were required to demonstrate in order to meet the standard, and that the data were *reported* at the standards level, the most general, broad statement of student activities or skills. It also is important to note that the Webb protocol required that assessment items and objectives *fully* match, and did not allow for *partial* matches. Thus, if an assessment item targeted only part of an objective, the reviewer could not consider it a match (Webb, Alt, Ely, & Vesperman, 2005; Webb et al., 2006). Finally, it should be noted that the alignment protocol assumed the standards were spanned by their underlying objectives, and that there was no activity or skill identified by a standard that was not specified by at least one of the objectives within it (Webb, Alt, Ely, & Vesperman; Webb et al., 2006).

In the current study, reviewers coded an assessment item as corresponding to as many as three objectives within a standard (one primary and up to two secondary objectives), or as uncodeable, *fully* matching no objectives within a standard. The pairwise agreement statistic was calculated for the overall alignment study. Reasonable pairwise agreement at the standards level was benchmarked at .6. A value of .7 was considered good agreement. A statistic of .5 was considered poor agreement (Webb, Alt, Ely, & Vesperman, 2005). The standards pairwise agreement statistic for the current study was .6 (5.995), indicating reasonable agreement, as shown in Appendix D, the DOK Levels and Objectives Coded by Each Reviewer Report.

## Reviewer Agreement

**Categorical concurrence**. Complete reviewer agreement neither is expected nor required to demonstrate acceptable levels of alignment (Conley et al., 2011; Webb, Herman, & Webb, 2006). The current study did not require a minimum level of reviewer agreement for the categorical concurrence criterion. In the Webb protocol, after consensus is reached on the DOK levels of the standards, each assessment item is assigned a DOK level, and up to three objectives are identified as corresponding to the item. Reviewer judgments about categorical concurrence, range of knowledge, and balance of representation are made based upon these ratings. As mentioned in the previous section, the Webb protocol records item match data at the *objectives* level, but computes and reports alignment at the *standards* level.

Webb et al. (2007) noted that conclusions about alignment between standards and assessment items vary, depending on whether reviewers are required to agree on the specific objectives within a standard that were matched to an assessment item and, if so, the level of agreement required. For example, alignment is determined by the mean number of items matched, averaged across reviewers (Webb et al., 2007). When reviewers are not required to agree on the specific objectives within a standard that are matched to an item, then every reviewer's item-objective matches are included in the alignment analysis (Webb et al., 2007). By contrast, if rater agreement is required, either by a simple or super majority threshold, then only the item-objective matches with the specified majority of reviewer agreement are included in the analysis, which reduces the number of item-objective matches analyzed. With fewer matches included in the analysis when simple or super majority reviewer agreement is required, the level of alignment is lower (Webb et al., 2007).

Categorical concurrence is higher when reviewers are not required to agree on specific item-objective matches, and falls substantially with each requirement of an agreement threshold, because rater disagreement reduces the number of items included in the analysis (Webb et al., 2007). Since the intent of the categorical concurrence criterion is to determine of the number of assessment items that correspond to each *standard*, then requiring agreement between the item and the specific *objective* within the standard is an unnecessarily narrow constraint for categorical concurrence (Webb, Alt, Ely, Cormier, et al., 2005; Webb et al., 2007). Webb et al. (2007) noted reviewer disagreement in a substantial number of items-objective matches and different conclusions about alignment, based on the level of reviewer agreement required.

**Depth-of-knowledge consistency.** For depth-of-knowledge consistency, conclusions about alignment were essentially the same whether or not reviewer agreement was required. When agreement was required, however, the DOK criterion analysis was based on only a minority of assessment items, since the agreement requirement reduces the number of items included in the analysis (Webb et al., 2007). Appendix D shows the DOK levels of the assessment items with their targeted objectives, by reviewer. Consistent with Webb et al.'s (2007) observation, the data suggested that when the matches were at the more specific item-objective level, objective pairwise agreement was unacceptably low at .2. When the matches were at the more broadly stated item-standard level, however, standard pairwise agreement was .6 (.5995), an adequate level of reviewer agreement.

## Research Findings

Using the Webb protocol, six reviewers evaluated content coverage, cognitive complexity, and breadth of coverage between the standards and assessment items along the criteria of categorical concurrence, depth-of-knowledge consistency, range of knowledge correspondence, and balance of representation. Each of the four criteria represents a different aspect of alignment, and alignment in all four alignment criteria were required to reach a determination of full alignment (Webb, 2007). Reviewers assigned a depth-of-knowledge level to each objective within the standards, reached consensus on the DOK levels, then assigned a DOK level to each assessment item, and either matched each item to one primary objective and up to two secondary objectives, or indicated the item was uncodeable, as no specific objective within the standard required the student activity measured by the assessment item.

The study found varying degrees of alignment between the standards and assessment in the four content-focused criteria, ranging from almost complete alignment on two criteria, to partial alignment in another, and complete non-alignment in another. Table 22 summarizes the achievement of alignment for each standard by criterion. “YES” indicates an acceptable level of alignment was achieved on the specified alignment criterion. “WEAK” suggests alignment almost was achieved and was within an acceptable margin of error for the criterion, as outlined in Table 21. “NO” indicates alignment was not achieved for the criterion by a margin above the margin of error (Webb, 2003; Webb, Alt, Ely, & Vesperman, 2005; Webb et al., 2006).

The standards and assessment were partially aligned on the categorical concurrence criterion. The assessment had an adequate number of items that targeted the standards in the Number and Quantity, Algebra, and Interpreting Functions conceptual categories, but an insufficient number of items that addressed the Geometry and Statistics and Probability to reach the acceptable level of alignment. Alignment in depth-of-knowledge consistency was achieved for all of the standards except Geometry, which was weakly aligned. Alignment was not reached for any standards for the range of knowledge criterion. Balance of representation was aligned in all standards except Number and Quantity, which was weakly aligned. The following sections present the findings by research questions.

Table 22

*Summary of Attainment of Acceptable Alignment Levels for Four Content-Focused Criteria as Rated by Six Reviewers; Number of Assessment Items: 45*

| Standards | Alignment Criteria | | | |
|---|---|---|---|---|
| | Categorical Concurrence | Depth of Knowledge Consistency | Range of Knowledge | Balance of Representation |
| 1. Number and Quantity | YES | YES | NO | WEAK |
| 2. Algebra | YES | YES | NO | YES |
| 3. Interpreting Functions | YES | YES | NO | YES |
| 4. Geometry | NO | WEAK | NO | YES |
| 5. Statistics and Probability | NO | YES | NO | YES |

## Quantitative Findings

**Overarching research question.** The overarching research question framing the study was: To what extent will successful completion of mathematics courses as prescribed by the California Common Core Content Standards for Higher Mathematics (9-12) lead to mastery of the skills required for college-level math placement as determined by the California State University Entry-Level Mathematics placement test? The overarching answer is that students who successfully complete the CA CCSSM-prescribed courses easily would develop mastery of the skills to meet the college-ready mathematics standards as represented by the ELM placement test. The current study indicated that the standards exceed the number of math topics, content coverage, cognitive demand, and span of knowledge included in the assessment. The skills required to answer the items correctly were less cognitively demanding than the skills prescribed by the standards. There are no mathematics knowledge and skills measured by the assessment that are not included in the standards.

**Research question 1.** To what extent are the California Common Core Content Standards for Higher Mathematics (9-12) aligned with the California State University Entry-Level Mathematics placement test?

***Categorical concurrence.*** Content match is a general indicator of alignment (Webb, Alt, Ely, & Vesperman, 2005). The categorical concurrence statistic measures content match between the standards and assessment items. The criterion is a proxy for the average number of assessment items that match a standard or its underlying objectives, and is achieved if the standards and assessment incorporate the same or consistent content categories. An acceptable level of alignment is reached if at least six assessment items are mapped to the standards, described as the number of assessments items that “hit” a standard.

Table 23 presents summary alignment statistics and findings regarding categorical concurrence. The first three columns enumerate the standards by conceptual category, number of standards, and number of objectives within the standards. It is important to note that, because reviewers could identify up to three objectives as corresponding to each assessment item, and the assessment tool gives the objectives equal weight in the alignment analysis, the number of objectives listed for each standard in the table could exceed the actual number of objectives in the standard (Webb, Alt, Ely, & Vesperman, 2005). The second three columns present the depth-of-knowledge level of the objectives, and the number and percentage of objectives within the standard by the level of cognitive demand. The last three columns list the mean number of hits, standard deviation, and whether categorical concurrence was achieved. The mean number of hits is the number of assessment items mapped to an objective within a standard, averaged across reviewers. At least six items must be mapped to an objective to achieve alignment. Findings for categorical concurrence are provided in the following section by conceptual category.

Table 23

*Categorical Concurrence Between the CA-CCSSM (9-12) and the CSU ELM as Rated by Six Reviewers; Number of Assessment Items: 45*

| Standards | | | Level by Objective | | | Hits | | Cat. Concurr. |
|---|---|---|---|---|---|---|---|---|
| Title | Goals # | Objs # | DOK Level | # of Objs by Level | % Objs w/in Std by Level | Mean | S.D. | |
| 1. Number and Quantity | 9 | 32.5 | 1 | 18 | 56 | 6 | 2.28 | YES |
| | | | 2 | 13 | 40 | | | |
| | | | 3 | 1 | 3 | | | |
| 2. Algebra | 11 | 35 | 1 | 11 | 31 | 13.5 | 3.95 | YES |
| | | | 2 | 18 | 51 | | | |
| | | | 3 | 6 | 17 | | | |
| 3. Interpreting Functions | 10 | 53 | 1 | 4 | 7 | 6.17 | 2.79 | YES |
| | | | 2 | 36 | 67 | | | |
| | | | 3 | 12 | 22 | | | |
| | | | 4 | 1 | 1 | | | |
| 4. Geometry | 15 | 49.33 | 1 | 2 | 4 | 4.83 | 3.18 | NO |
| | | | 2 | 18 | 36 | | | |
| | | | 3 | 29 | 59 | | | |
| 5. Statistics and Probability | 9 | 36.33 | 1 | 1 | 2 | 4.33 | 2.47 | NO |
| | | | 2 | 16 | 44 | | | |
| | | | 3 | 17 | 47 | | | |
| | | | 4 | 2 | 5 | | | |
| Total | 54 | 206.17 | 1 | 36 | 17 | 34.83 | 11.10 | |
| | | | 2 | 101 | 49 | | | |
| | | | 3 | 65 | 31 | | | |
| | | | 4 | 3 | 1 | | | |

*Note*: “If the number of objectives in the table is greater than the actual number in the standard, then at least one reviewer coded an item for the goal/objective but did not find any objective in the goal that corresponded to the item” (Webb, Alt, Ely, & Vesperman, 2005, p. B-12).

*Number and quantity.* Content alignment was reached for standards in the Number and Quantity conceptual category. There were 9 standards and 32.5 objectives (32 actual) in this grouping. Six assessment items hit objectives within the standard, reaching the minimum number of items required to meet the alignment threshold. The standard deviation was 2.28.

*Algebra*. There was content alignment for the topic of Algebra. There are 11 standards and 35 objectives (34 actual) in this content area. This conceptual category showed the strongest degree of alignment, with 13.5 assessment items mapped to objectives within the standard. The standard deviation was 3.95.

*Interpreting functions*. An acceptable level of content alignment was reached for Interpreting Functions. The category includes 10 standards and 49.33 objectives (45actual). With 6.17 mean hits, the conceptual category met the minimum threshold for alignment. The standard deviation was 2.79.

*Geometry*. Content alignment was not attained Geometry. There are 15 standards and 49.33 objectives in the category (45 actual). Only 4.83 assessment items were mapped to objectives within the standard. Standard deviation was 3.18.

*Statistics and probability.* Content alignment was not reached for the topic of Statistics and Probability. There are 9 standards and 36.33 objectives (36 actual). The 4.33 assessment items matched to objectives failed to meet the alignment threshold. The standard deviation was 2.47.

*Uncodeable items.* An item was rated as "uncodeable" if any reviewer considered it not to match the content of any standard or objective. Reviewers did not have to agree on items judged as uncodeable, although multiple reviewers did agree on many of the items. Table 24 is a listing of items rated as unmatched, and Table 25 collapses the data by the number of reviewers who rated the items as uncodeable. Tables 24 and 25 show that 71% of the items (32 out of 45) were

Table 24

*Uncodeable Assessment Items*

| Item # | # of Reviewers Who Marked the Item as Uncodeable |
|---|---|
| 1 | 4 |
| 3 | 5 |
| 5 | 4 |
| 6 | 3 |
| 7 | 1 |
| 9 | 2 |
| 10 | 5 |
| 11 | 2 |
| 12 | 3 |
| 13 | 3 |
| 15 | 4 |
| 17 | 3 |
| 20 | 4 |
| 21 | 3 |
| 22 | 5 |
| 23 | 4 |
| 28 | 1 |
| 29 | 2 |
| 30 | 3 |
| 31 | 2 |
| 32 | 5 |
| 33 | 1 |
| 35 | 2 |
| 37 | 2 |
| 38 | 1 |
| 39 | 3 |
| 40 | 4 |
| 42 | 2 |
| 45 | 2 |
| 47 | 3 |
| 48 | 3 |
| 50 | 1 |

rated by at least one reviewer as not matched to any objective. The issue of reviewer agreement was presented earlier in this chapter.

Table 25

*Uncodeable Assessment Items by Reviewer Agreement*

| # Reviewers | Uncodeable Items |
|---|---|
| 6 | 21 |
| 5 | 10, 22, 32 |
| 4 | 1,3,5,15,20, 23, 40 |
| 3 | 6,12,13,17,21,22,39,47,48 |
| 2 | 9, 11, 27, 31, 35, 37, 42, 45 |
| 1 | 7, 28, 33, 38, 50 |
| Total | 32 |

**Research question 2.** What cognitive demands are emphasized in the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University Entry-Level Mathematics placement test, respectively?

***Depth-of-knowledge consistency.*** To determine the consistency between the complexity of knowledge required by the standards and assessment, reviewers rated the depth of knowledge of the objectives and the assessment items using the Marzano (2001) scale of increasing cognitive complexity: Level 1 (retrieval); Level 2 (comprehension); Level 3 (analysis); and Level 4 (knowledge utilization). Reviewers individually assigned depth-of-knowledge levels to the objectives, reached consensus on the DOK levels, then individually assigned DOK levels to the assessment items, and identified up to three objectives as corresponding to the item. Appendix E is the Group Consensus on DOK Levels of Objectives Report.

Depth of knowledge consistency is attained if at least 50% of the assessment items matched to an objective are at the same or higher level of cognitive complexity as the objectives they target. Two tables explicate the findings. In Table 23, the second set of three columns summarizes the consensus

DOK levels by number and percentage of objectives at each cognitive level, by conceptual category. Table 26 reports the mean percentage and standard deviation of assessment items that were rated under, at, or above the DOK level of the matched objective. Each conceptual category achieved an acceptable level of alignment, although cognitive alignment was weak in Geometry. The DOK statistics in Tables 23 and 26 are detailed in the following sections by conceptual category.

Table 26

*Depth-of-Knowledge Consistency Between the CA-CCSSM (9-12) and the CSU ELM as Rated by Six Reviewers; Number of Assessment Items: 45*

| Standards | | | Hits | | DOK of Item with regard to the Standard | | | | | | DOK Consistency |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % Under | | % At | | % Above | | |
| Title | Goals # | Objs # | M | S.D. | M | S.D. | M | S.D. | M | S.D. | |
| 1. Number and Quantity | 9 | 32.5 | 6 | 2.28 | 44 | 48 | 41 | 43 | 14 | 28 | YES |
| 2. Algebra | 11 | 35 | 13.5 | 3.95 | 43 | 49 | 37 | 45 | 20 | 37 | YES |
| 3. Interpreting Functions | 10 | 53 | 6.17 | 2.79 | 44 | 47 | 32 | 41 | 24 | 39 | YES |
| 4. Geometry | 15 | 49.33 | 4.83 | 3.18 | 51 | 49 | 36 | 47 | 13 | 34 | WEAK |
| 5. Statistics and Probability | 9 | 36.33 | 4.33 | 2.47 | 25 | 42 | 42 | 45 | 33 | 44 | YES |
| Total | 54 | 206.17 | 34.83 | 11.10 | 42 | 48 | 37 | 44 | 21 | 37 | |

*Number and quantity.* Table 23 shows that 56% of the objectives in the category were rated at Level 1 (retrieval), the lowest cognitive level; 40% were rated at Level 2 (comprehension); and one objective, or 3%, was rated at Level 3 (analysis). No objectives in the category were rated at Level 4 (knowledge utilization). Table 26 shows that a mean of 44% of the math placement assessment items were rated at a lower cognitive level than the targeted objectives. Forty-one percent were at the same level, and 14% were at a higher cognitive level. Since 55% of the items were at or above the cognitive level of the associated objectives, the alignment criterion was met.

*Algebra*. Table 23 shows that almost one-third (31%) of the Algebra objectives were rated at Level 1; half (51%) were rated at Level 2; and 15% were rated at Level 3. No algebra objectives were rated at Level 4. In Table 26, a mean of 43% of the assessment items were at a lower cognitive level than the corresponding objectives. Thirty-seven percent were at the same level, and 20% were above the depth of knowledge level. The 57% of items at or above the cognitive level of the objectives indicated an acceptable level of alignment.

*Interpreting functions.* Table 23 shows that 7% of the objectives were rated at Level 1; 67% at Level 2; 22% at Level 3; and 1 item (1%) at Level 4. Table 26 shows that a mean of 44% of the items were below the cognitive level of the targeted objectives. Thirty-two percent were at-level, and 24% were above level. The category reached an acceptable level of alignment with 56% of the items at or above the cut-off level.

*Geometry.* Table 23 shows that 4% of the objectives were rated at Level 1; 36% at Level 2; and 59% at Level 3. No objectives were rated at Level 4. Table 26 shows that a mean of 51% of the items fell below the cognitive level of the corresponding objectives. Thirty-six percent were at the same level, and 13% were above the depth of knowledge level. Although the 49% of items at or above the cognitive level did not meet the alignment cut-off, the value is within 10% of the threshold, earning the category a determination of weak cognitive alignment, rather than no alignment.

*Statistics and probability.* Table 23 shows that the cognitive level was primarily at Levels 2 and 3, with only 1 item (2%) at Level 1; 44% at Level 2; 47% at Level 3; and 5% at Level 4. Table 26 shows that a mean of 75% of the items were at or above the cognitive level of the objectives, with 42% at the same level, 33% above, far exceeding the threshold for alignment. Twenty-five percent of the items were lower than the cognitive level of the targeted objectives.

*Overall cognitive comparison.* Table 27 compares the number and percentage of objectives and items within the DOK levels. The table shows that the assessment rarely calls for skills at the higher levels of cognitive demand. Students may apply predominantly (84%) Level 1 (retrieval) and Level 2 (comprehension) skills to answer assessment items correctly. Only15% of the items require analysis at the more cognitively challenging Level 3 (analysis) depth-of-knowledge. No assessment items require the use of Level 4 skills (knowledge utilization).

Comparatively, although the standards place the greatest emphasis at Level 2 (49%), their focus on Level 1 skills is 17%, substantially less than in the assessment items. Almost one-third (31%) of the objectives call for Level 3 skills, and a few of the objectives require the highest level of cognitive demand.

Table 27

*Number and Percentage of Items and Objectives Within Each Depth of Knowledge Level as Rated by Six Reviewers; Number of Assessment Items: 45*

| Assessment/ Standard | Level 1 | | Level 2 | | Level 3 | | Level 4 | |
|---|---|---|---|---|---|---|---|---|
| | #Items/ Objs | % Items /Objs | #Items /Objs | % Items /Objs | #Items | % Items /Objs | #Items /Objs | % Items /Objs |
| ELM | 19 | 42 | 19 | 42 | 7 | 15.5 | 0 | 0 |
| CCSSM | 36 | 17 | 101 | 49 | 65 | 31 | 3 | 1 |

**Research question 3.** What is the alignment between the breadth of knowledge of the standards and the assessment? Breadth is evaluated on two criteria – range of knowledge correspondence and balance of representation.

***Range of knowledge correspondence***. The range of knowledge criterion measures the consonance between the span of knowledge students are expected to acquire based on the standards, and the span of knowledge students are required to have to answer correctly the assessment items that correspond to the standard. The scale is 0 to 1.0 and the benchmark for an acceptable level of alignment is .5. Alignment is reached if at least 50% of the objectives within a standard have at least one corresponding assessment item, meaning that an adequately-aligned assessment focuses on at least half of the objectives within a standard. Weak alignment is reached if 41-49% of the standards have a related assessment item.

In the current study, no standards in any conceptual category met the range of knowledge criterion or even approached an acceptable level of alignment. As shown in Table 28, a scant 8% of the objectives in Number and Quantity (2.5 out of 32.5) had a corresponding assessment item. For the criterion to be reached in this category, at least 16 objectives would have to have been targeted, whereas only 2.5 objectives were judged to have a corresponding assessment item. For the Algebra objectives, 23% (8.17 out of 35) had corresponding items, as did 7% (3.83 out of 35) in Interpreting Functions; 8% in (3.83 out of 49.33) Geometry; and 8% (3 out of 36.33) in Probability and Statistics. The Item Agreement Report in Appendix F lists the objectives and indicates the assessment items coded to each objective, color-coded by the number of reviewers who coded the item the same (the number of reviewers who agreed on the item). The Item Agreement Coverage Report in Appendix G is the converse, listing the assessment items and indicating the objectives coded as being covered by each item. The objectives are color-coded by the number of reviewers who had the same coding.

***Balance of representation.*** The balance of representation criterion pertains only to objectives with corresponding assessment items and measures whether the objectives within a standard are emphasized equally in the assessment or whether the objectives are clustered around a few items (Webb et al., 2005). An index value of 1 indicates equal distribution and values approaching 0 indicate that only one or two of the objectives were targeted. The cut-off for alignment is .7, indicating good distribution of the objectives, while a value between .6 and .7 indicates weak alignment. Table 28 shows that the Number and Quantity objectives were weakly aligned with a value of .6, and all other standards achieved an acceptable level of alignment. Geometry objectives were almost perfectly balanced among their corresponding items, with a distribution value of .94. Algebra objectives were well distributed with a value of .80, respectively, followed closely by Interpreting Functions with a balance index of .79, and Statistics and Probability at .73.

## Qualitative Findings

**Source of challenge.** The criterion pertains to the depth-of-knowledge of the assessment items and whether the cognitive complexity in correctly answering a question stemmed from the math skill inherent to the item or whether item difficulty arose from issues external to the targeted math skill (Webb et al., 2005). Appendix H, the Source of Challenge Report, presents reviewer perspectives on the origin of an item’s complexity, if any. Two prominent issues arose. One frequently-occurring issue related to the cognitive demand of reading, manifested through two words – “words” and “reading.” “Words” is defined in this context as

Table 28

*Range-of-Knowledge Correspondence and Balance of Representation Between the CA-CCSSM (9-12) and CSU ELM as Rated by Six Reviewers; Number of Assessment Items: 45*

| Standards | | | Hits | | Range of Objectives | | | | Rng. of Know. | Balance Index | | | | Bal. of Represent. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | # Objs Hit | | % of Total | | | % Hits in Std/Ttl Hits | | Index | | |
| Title | Goals # | Objs # | Mean | S.D. | Mean | S.D. | Mean | S.D. | | Mean | S.D. | Mean | S.D. | |
| 1 - Number and Quantity | 9 | 32.5 | 6 | 2.28 | 2.5 | 1.20 | 8 | 3 | NO | 17 | 9 | 0.60 | 0.16 | WEAK |
| 2 – Algebra | 11 | 35 | 13.5 | 3.95 | 8.17 | 1.77 | 23 | 5 | NO | 41 | 10 | 0.80 | 0.04 | YES |
| 3 - Interpreting Functions | 10 | 53 | 6.17 | 2.79 | 3.83 | 1.86 | 7 | 4 | NO | 18 | 9 | 0.79 | 0.10 | YES |
| 4 – Geometry | 15 | 49.33 | 4.83 | 3.18 | 3.83 | 1.95 | 8 | 4 | NO | 13 | 6 | 0.94 | 0.09 | YES |
| 5 - Statistics and Probability | 9 | 36.33 | 4.33 | 2.47 | 3 | 1.73 | 8 | 5 | NO | 11 | 6 | 0.73 | 0.18 | YES |
| Total | 54 | 206.17 | 34.83 | 11.10 | 4.27 | 2.56 | 11 | 7 | | 20 | 13 | 0.77 | 0.12 | |

indicating that words were included in the test item stem, or words had to be translated into an equation in order to solve the math problem, which contributes to item difficulty (Embretson & Daniel, 2008). The issue appeared in the source-of-challenge comments 17 times, more than twice any other singular concern. Relatedly, “reading,” defined for the purpose of this study the same as “words,” appeared twice.

The other key source of item difficulty was prerequisite knowledge at the middle school or even grade school level. The issue was evidenced from reviewer references to various math skills that are expected to be learned in middle school or earlier grade levels. “Fractions,” for example, refer to parts of a whole number and are a fourth grade math skill, cited eight times in the context of being pre-requisite knowledge required to answer the test item correctly. “Middle school,” defined as the seventh and eighth grades, appeared five times, and indicated that an item’s cognitive complexity was at the middle school skill level or required prerequisite knowledge at the middle school level. “Percents” (Percentages), listed four times, means parts per 100 and was referenced as a sixth grade math skill. While the skills are not cognitively complex, the reviewers indicated that a lack of mastery of these prerequisite skills is a source of challenge to answering the item correctly.

Appearing only twice, but worth noting, was “picture” in the context that one item required a picture to be drawn and another included a picture that the reviewer noted as difficult to visualize, both of which were required to solve the problem, and contributed to the items’ difficulty. Three reviewers mentioned an item that used the phrase “tread depth,” which they did not define, but possibly refers to the depth of treads on a tire. Reviewers noted that unfamiliarity with the term could be a source of challenge would discourage students from attempting to answer the question. The item also was a word problem which reviewers noted could add to item difficulty.

**Reviewer notes**. When coding the assessment items and assigning corresponding objectives, reviewers were given an opportunity to make unrestricted notes about the assessment items. The Notes by Reviewer Report in Appendix I tracked almost perfectly with Table 24, Uncodeable Assessment Items. A side-by-side reading of Appendix I and Table 24 revealed the reasons reviewers judged the uncodeable items as not matching any objectives in the standards. Almost to an item, the notes described the items as being at a middle school level, most often mentioning sixth, seventh, or eighth grade, and some mentioning fourth and fifth grade math skills.

**Debriefing summary**. Upon completion of the alignment analysis, reviewers were asked to answer five open-ended debriefing questions. No limitations were placed on the length of their responses. Reviewers completed the surveys independently.

*A. For each competency, did the items cover the most important topics you expected on the competency? If not, what competency was not appropriately covered and what topics were not assessed that should have been?*

The Debriefing Summary by Reviewer Report in Appendix J presents reviewers' responses. Reviewers were unanimous in their judgments that the assessment did not cover the objectives sufficiently. Each noted that some standards were not covered at all, and some noted that standards were over-targeted, with too many assessment items addressing the same standards, asking the same thing in many different ways. Several commented that the items did not align because they are prerequisite middle school material. Of the standards that were addressed, the most important topics were covered well. One reviewer expressed surprise that there were not more Geometry and Algebra II-based questions. Another noted that few questions addressed basic functions (quadratic, exponential, polynomial, etc.).

*B. For each competency, did the items cover the most important performance (DOK levels) you expected on the competency? If not, what competency was not assessed at an appropriate depth-of-knowledge level and how should the assessment of the competency be improved?*

All of the reviewers noted that the assessment items primarily were DOK Level 1 and 2, requiring basic rote procedures. Some were surprised that there were not more Level 3 items. Others noted that the multiple choice and timed format of the assessment relegated even Level 3 and Level 4 standards to being assessed at Level 1 and 2, and that Level 3 learning objectives are better assessed by written responses, not multiple choice questions.

*C. Were the standards written at an appropriate level of specificity and directed towards expectations appropriate for the grade level?*

Reviewers were split evenly, with half indicating the standards are specific and grade-appropriate (two higher education and one high school reviewer). Of the three who considered the level of specificity inappropriate, one believed the standards are too specific to some college majors and a few careers to be the standard by which all students should be considered college- and career-ready. One deemed the standards more broadly written than the easily-assessed previous standards, and the third believed too many questions addressed middle school and basic high school standards.

*D. What is your general opinion of the alignment between the competencies and assessment?*

*i. Perfect alignment*

*ii. Acceptable alignment*

*iii. Needs slight improvement*

*iv. Needs major improvement*

*v. Not aligned in any way?*

No reviewer believed the standards and assessment had perfect alignment or acceptable alignment, nor did any reviewer believe they were not aligned in any way. All six reviewers believed the alignment between the standards and assessment needed improvement, with 67% (four reviewers) indicating slight improvement is needed, and 33% (two reviewers) indicating major improvement is needed. All of the higher education faculty and one high school instructor believed slight improvement was needed, while the two high school instructors believed major improvement was needed.

*E. Other comments?*

One reviewer commented that the assessment appropriately addressed prerequisite sixth- through eighth-grade topics. Another believed the items were aligned to the objectives; however, they lacked depth and variety. Another reiterated a position that the ELM and Common Core standards are not aligned, and another restated the importance of having written responses to assess the higher cognitive demand levels.

## Summary of Findings

Six high school and higher education mathematics educators participated in the alignment analysis of the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University's Entry-Level Mathematics placement assessment. Using the Webb (1997, 1999, 2002) alignment protocol, reviewers rated the content, cognitive complexity, and breadth of the objectives and items to measure alignment against four content criteria: 1) categorical concurrence; 2) depth of knowledge consistency; 3) range of knowledge; and 4) balance of representation. The study found partial alignment across the criteria, with areas that met the alignment criteria, another with weak alignment, and one with no alignment.

Three of the five conceptual categories had the same or consistent content that met the alignment criterion; namely, Numbers and Quantity, Algebra, and Interpreting Functions. Two conceptual categories were not aligned: Geometry and Statistics and Probability. More than two-thirds of the assessment items (32 items, 71%) were coded by at least one reviewer as not matching any objective fully, designating the items as uncodeable.

Depth-of-knowledge was aligned in all conceptual categories, but only weakly aligned in Geometry. Multiple reviewers rated the cognitive level of many assessment items as middle school level. Reviewers noted that the challenge with correctly answering many of the assessment items had to do with understanding the reading required to answer the questions. No standards were aligned in the range of knowledge criterion. Balance of representation was aligned for all standards, but only weakly aligned for Number and Quantity. The following chapter discusses the findings and makes recommendations.

# CHAPTER 5: DISCUSSION/SUMMARY/CONCLUSION

The purpose of this study was to determine the extent to which the California Common Core Content Standards for Higher Mathematics (9-12) were aligned with the California State University system's Entry-Level Mathematics placement assessment. Standards are broad statements of what all students should know and be able to do in a subject matter by a particular grade level or at completion of a level of education. College placement tests assess first-year students' subject-specific content knowledge, and placement test results are used to make inferences and decisions about student proficiency to place students into the highest-level course in a discipline's course sequence in which they are most likely to succeed.

The study used six high school and higher education mathematics instructors as subject matter experts to conduct a comparative content analysis to determine the alignment between the placement assessment and the standards. Reviewers judged alignment along four content-focused criteria: categorical concurrence; depth of knowledge; range of knowledge; and balance of representation, with established levels of attainment using the Webb (1997, 2002) alignment analysis method. Each of the four criteria represents a different aspect of alignment and all four alignment criteria must be met for a determination of full alignment (Webb, 2007). The math standards' five domains included: Number and Quantity; Algebra; Interpreting Functions; Geometry; and Statistics and Probability. This chapter summarizes and discusses the research findings presented in Chapter Four regarding the extent of alignment achieved, and relates the findings to the research literature and the theoretical framework. Recommendations include modifications that can be made to the assessment to increase alignment with the standards. Implications for practice and study limitations follow. The chapter concludes with suggestions for further research.

## Summary of Findings

Study findings indicated that the ELM was partially aligned with the California Common Core math standards for grades 9-12, with uneven alignment in content topics, cognitive complexity, span of knowledge, and distribution objectives among the assessment items. The placement test covered fewer math topics, at a lower cognitive level, within a narrower range of knowledge than did the standards. Specifically, content was aligned in the Number and Quantity, Algebra, and Interpreting Functions domains; however, the ELM had an insufficient number of items in Geometry and Statistics and Probability to meet the content alignment criterion. Depth of knowledge was aligned in all categories, but only weakly aligned in Geometry, and at the lower levels of cognitive complexity. The span of knowledge elicited from the assessment items was not comparable to the span of knowledge required of the standards for any category. Objectives were distributed evenly among the assessment items, indicating that they were given equal emphasis across the items with the exception of Number and Quantity, where two objectives accounted for the bulk of the alignment, at the expense of the other objectives.

Reviewers noted multiple sources of challenge to the assessment items, for example, that difficulty in answering the item correctly arose from an issue other than the skill being assessed in the item. The six reviewers were unanimous in their judgment that the level of alignment between the ELM and the Common Core math standards needs improvement. One-third of the reviewers, both of whom were at the high school level, opined that the alignment needed major improvement while two-thirds, including all of the higher education and one high school reviewer, suggested that the assessment needed only slight improvement. A discussion of these findings follows.

## Discussion

### Standard Deviation and Reviewer (Dis)Agreement

Lombardi et al. (2010) asserted that basic questions about rater reliability in alignment studies either are ignored or are insufficiently investigated without critical examination using empirical evidence. To examine the generalizability of ratings across raters, differentiate sources of error variance, and determine the ideal number of raters required for the greatest generalizability of assessment-standards ratings, Lombardi et al. conducted a generalizability theory study of cognitive demand and rigor ratings, using reviewers as sources of error in a Webb (1997, 1999) alignment analysis of mathematics and ELA assessment/college-readiness standards. The study differentiated cognitive demand from rigor, defining cognitive demand as "the level of information processing and the degree of conscious thought needed to complete a task" (p. 6), and rigor as "focus[ing] not only on the mental activity required to answer an item successfully or to perform the expectation stated in the standards, but on the relative challenge and difficulty of doing so" (Lombardi et al., 2010, p. 7). Investigators used the level at which an entry-level college student is expected to perform as the reference point. The cognitive demand scale was Levels 1-4 of the Marzano (2001) taxonomy, and rigor was rated on a lowest-to-highest scale of 1-3, defined as *below, at,* or *above* the level at which an entry-level college student is expected to perform, respectively (Lombardi et al., 2010).

The Lombardi et al. (2010) study findings indicated that:

- Rater reliability was greater for math than for English (suggested as stemming from math being more objective and English more subjective); and
- Rater reliability was greater for the cognitive demand scale (Marzano scale) than for the rigor scale (subjective descriptors open to interpretation).

Perhaps most pertinent to the current study and the issue of rater reliability, findings in Lombardi et al. (2010) indicated that:

- Six was shown to be an appropriate number of raters for math and cognitive demand, but possibly an inadequate number for English and scales comparable to the study's rigor scale;
- Sources of error variance were greater for cognitive demand than rigor; and
- Sources of error variance were greater for ratings conducted independently as opposed to synchronously in a group setting.

In the current study, reviewers conducted the ratings independently. Even though the current study achieved a reasonable standard pairwise agreement level (.6) and an adequate intraclass correlation value (.7), both evidencing interrater reliability, Lombardi et al.'s (2010) findings suggest that variance among raters might have been lower and agreement higher had the ratings been conducted in a setting that allowed greater interaction among the raters.

Herman et al. (2005) conducted a generalizability study using 20 highly qualified UC faculty and high school instructors (10 each) to rate the mathematics items on the Golden State Examination and the University of California *Statement on Competencies in Mathematics.* Herman et al. considered 20 raters as the gold standard full complement of reviewers and compared the panel's rater reliability results to more than 14,000 subsets of six reviewers, the number of raters used in typical alignment analyses, and the minimum number considered essential for reliability of results. Both groups showed:

- fair to moderate rater agreement on assigning assessment items to content topics, with considerable variability in rater agreement;
- a steep drop in rater agreement regarding specific item-to-topic matches;
- moderate agreement regarding depth of knowledge, with large standard errors of measurement, and considerable differences in high school instructors' and university faculty's perceptions of DOK, item complexity, and multidimensionality (whether an assessment addressed one or more primary topics); and
- the six-member panels "overestimated" (p. 28) alignment compared to the 20-member panel (Herman et al., 2005).

The study's findings strongly suggested that even with raters highly qualified in content knowledge and experience, additional rater training is required to ensure more consistency among reviewers. More importantly, as pertains to the considerable variation in reviewer agreement in the current study, Herman et al. (2005) indicated:

> Agreement in the assignment of ratings can be considered an indicator of the extent to which common understandings are shared. Similarly, lack of agreement on the relationship between content topics and items suggests that educators operate with diverse definitions of the meanings of standards in terms of content and depth-of-knowledge expectations…Our findings suggest that even highly experienced educators with solid content credentials can experience difficulty applying standard definitions of content and cognitive demand…Considering the expertise and experience of the educators and faculty who were involved in this study…our findings may well represent a best case… (p. 31).

## Research Questions

**Overarching research question.** *To what extent will successful completion of mathematics courses as prescribed by the California Common Core Content Standards for Higher Mathematics (9-12) lead to mastery of the skills required for college-level math placement as determined by the California State University Entry-Level Mathematics placement test?*

The overarching research question is an inquiry about the inter-relationship among curriculum components – the intended, taught/enacted, and tested curriculum. Standards are intended to guide instruction, and assessments test what was learned as the result of instruction. Figure 14 illustrates how curriculum components connect, the type of information solicited from studying the alignment between different components, and how instruction is implicit in, and essential to, alignment between standards and assessment. Student mastery requires that instruction shift to align with what was intended and what is tested (Anderson, 2002; Porter, 2002).

***Imperfect alignment.*** The study's finding of partial, imperfect alignment between the Common Core and the ELM does not preclude student mastery of the skills required for college-level math placement as determined by the ELM. In the present study, although the ELM does not assess all of the Common Core math standards, the standards include all of the ELM content. Thus, if students master the standards, they will have mastered all of the content assessed by the ELM.

**Research question 1.** *To what extent are the California Common Core Content Standards for Higher Mathematics (9-12) aligned with the California State University Entry-Level Mathematics placement test?*

The question was examined through the four content metrics of categorical concurrence, depth-of-knowledge consistency, range of knowledge, and balance of representation, with thresholds for acceptable levels of alignment established for each. The assessment and standards were only partially aligned in each criterion.

***Categorical concurrence.*** Findings indicated that the ELM did not achieve alignment (at least six item matches) in Geometry and Statistics and Probability; attained minimal alignment in the Number and Quantity and the Interpreting Functions domains; and far exceeded the alignment threshold in Algebra (Table 26). Since the ELM pre-dates the Common Core standards, the finding of only partial content alignment is not surprising. The ELM's three content areas are: Numbers and Data (35%); Algebra (35%); and Geometry (30%), compared to the Common Core's five topic areas: Number and Quantity, Algebra, Interpreting Functions, Geometry, and Statistics and Probability. It was expected that alignment would not be achieved in Statistics and Probability, since the domain is not listed in the ELM topic categories; however, the lack of alignment in Geometry was unanticipated. Geometry is a core ELM domain which 30% of the items were intended to target. Reviewers were surprised at how few Geometry items the ELM included (see Appendix J, Debriefing Summary by Reviewer Report). Interestingly, the research literature indicates that placement tests designed to place students into College Algebra typically devote less than 15% of their items to Geometry and measurement (Achieve Inc., 2007).

Appendix F, the Item-Agreement Report, details the content matches. The excessive blank spaces in Appendix F illustrate at a glance the inadequate targeting of the Geometry and Probability and Statistics standards. Interestingly, reviewer notes indicated the possibility that the number of item-objective matches actually could be lower, as some reviewers forced and "shoe-horned" some fits (Appendix I, Notes by Reviewer Report). For example, reviewer notes regarding Items 21, 23, 32, and 43 specifically refer to selecting the closest high school standard despite the standard not fitting, not matching the item perfectly, or being a bad fit.

*Steps to achieve alignment in categorical concurrence.* Given the data that there were only 35 mean hits (34.8), and that 32 items were rated by at least one reviewer as uncodeable (not matching the content of any objective), ample opportunity exists to bring the category into alignment (see Table 26, "Hits" column , and Tables 27 and 28). To achieve categorical concurrence in Geometry and in Statistics and Probability, each conceptual category must have at least six item-objective matches. Geometry requires that two additional items address the standard, as does Statistics and Probability; thus, four existing assessment items can be changed to target objectives within the standards. The four items could be taken either from the pool of 15 unmatched items, or from the surplus of items that target Algebra. Neither action would affect the total number of assessment items.

**Research question 2.** *What cognitive demands are emphasized in the California Common Core Content Standards for Higher Mathematics (9-12) and the California State University Entry-Level Mathematics placement test, respectively?*

The ELM "is designed to assess and measure the level of mathematics skills acquired through three years of rigorous college preparatory mathematics coursework (Algebra I and II, and Geometry)…" to satisfy the CSU's General Education quantitative reasoning graduation requirement for both quantitative and non-quantitative majors (CSU, 2009, p. 3). Although depth-of-knowledge consistency was aligned in all standards, but weakly so in Geometry, it is important to note that alignment was at the lower cognitive levels. A full 84% of the ELM test items were at Levels 1 and 2 -- 42% at Level 1 and 42% and Level 2 -- with 15.5% at Level 3, and none at Level 4 (Table 27). Thus, notwithstanding the CSU's stated intent that the ELM measure the content of rigorous high school math, few items measure higher cognitive levels, and none measure the highest level. The absence of Level 4 items on the ELM denies students the opportunity to demonstrate proficiency at the higher end of the cognitive demand spectrum.

In Algebra, 43% of the items were under the cognitive level of the corresponding standard, 37% were at the same level, and 20% were above the cognitive level (Table 26). Reviewers rated numerous skills as consistent with Algebra I taught in grades 6, 7, and 8. Figure 19 lists Algebra levels, their equivalent course titles, and examples of topics covered in the courses. Few items assess Algebra II, as indicated in the reviewers' notes (Appendix I, Notes by Reviewer Report, and Appendix J, Debriefing Summary).

| Algebra Level | Course Equivalent | Examples of Topics Covered |
|---|---|---|
| Prealgebra | Middle School Math/Prealgebra | Working with integers, rational numbers, patterns, representation, substitution, basic manipulation and simplification |
| Basic Algebra | Algebra I | Linear equations and basic functions and relations |
| Advanced Algebra | Algebra II | Non-linear equations or inequalities and an understanding of real and complex numbers |

*Figure 19*. Algebra levels, course titles, and topics covered. Achieve, Inc. 2007.

It appears clear that the ELM focuses on middle school-level Algebra I knowledge and skills rather than the intended Algebra II. Challenge in answering the items correctly appears not to be due to cognitive complexity; rather, due to lack of mastery of the skills in the earlier grades (Appendix H, Source of Challenge Issues Report). Similarly, more than half (51%) of the Geometry items were below the cognitive level of the corresponding standard. Slightly over one-third (36%) had the same cognitive depth, and 13% were above the cognitive level (Table 26).

*Steps to achieve alignment in cognitive demand*. The assessment has both content and cognitive misalignments in Geometry. As suggested in the previous section, to achieve content alignment, two items could be revised to target Geometry. The two items should be at the same or higher level of cognitive demand as their targeted objectives. Webb, Alt, Ely, and Vesperman (2005) suggested using the data in Table 26 and the following formula to determine the number of cognitively demanding items to add in order to meet the DOK consistency index of at least 50%: $H * (U – 50)$, where H represents the number of mean hits and U is the mean percentage of assessment items under the DOK level of the corresponding standard. For Geometry, the mean number of hits is 4.83 and 51% of the items are under the corresponding DOK level. According to the formula, $4.83(51 – 50) = 4.83$; thus, the DOK level of 4.83 Geometry items should be increased.

In Algebra, the 35 objectives had 13.5 matches, almost half (43%) of which were below the cognitive level of their corresponding objectives (Table 26). Some of these items can be rewritten to target unmatched or under-matched Level 3 objectives. For example, Appendix E, Group Consensus on DOK Levels of Objectives, shows objectives 2.5a, 2.7b, and 2.7c at Level 3, and Appendix F, the Item Agreement Report, shows that only one item was judged as addressing the content of 2.5a, one as addressing 2.7b, and no items as addressing 2.7c.

*High-quality assessments.* Darling-Hammond et al. (2013) defined a high-quality assessment as one that measures higher-order thinking skills. As a metric of whether an assessment measures higher-order thinking skills, Darling-Hammond et al. suggested that at least two-thirds of the items should be at DOK Levels 2, 3, or 4, reflecting transferrable conceptual knowledge and skills, and at least one-third should be at the higher cognitive levels, Level 3 and Level 4. Under this metric, the present study falls short with 57% of the items at Levels 2, 3, or 4, and 15% of items at Levels 3 and 4 (Table 27). To meet Darling-Hammond et al.'s metric, nine percent of the items (4.5 items) could be raised to Levels 2, 3, and 4 to achieve the two-thirds benchmark, and 18% (9 items) could be raised to Levels 3 and 4 to meet the one-third metric. In addition to assessing higher-order thinking skills, Darling-Hammond et al. cite four additional essential criteria for high-quality assessments: high-fidelity assessment of critical abilities; assessments that are internationally benchmarked; use of instructionally sensitive and educationally valuable assessment items; and the use of valid, reliable, and fair assessments.

*Time and format.* Reviewers noted that the format of the placement test limits its ability to assess higher cognitive levels (Appendix J, Debriefing Summary by Reviewer, Question B). The ELM is a time-limited, multiple-choice placement instrument. Students have 90 minutes to answer 50 questions, an average of one minute and 48 seconds per question. The ELM emphasizes problem-solving over computation (CSU, 2009). Problem-solving requires problem definition, analysis, and the selection and application of the mathematical skill that will yield the correct solution, which could be impeded both by time limitation and multiple choice format of the test (Yuan & Le, 2012). Geometry standards require students to prove and argue, which also could be constrained by the test format.

Yuan and Le (2012) asserted that the multiple choice format limits the opportunity for students to provide constructed responses to prove their abilities at the higher cognitive levels. Yuan and Le used Webb's (1997, 1999) DOK levels to analyze the rigor of 17 states' ELA and mathematics achievement tests considered to be cognitively demanding, including California's. The study analyzed more than 5,100 state assessment items from 201 assessments. Seventy-eight percent of the mathematics assessment items were multiple-choice. The study found the state assessments' cognitive rigor low, with open-ended items more likely to assess Level 3 and Level 4 than multiple-choice items. *All* of the math assessments' multiple choice items were at or below Level 2, and more than half were rated at Level 1. For California, 100% of the 767 math assessment items were multiple-choice. Seventy-four percent of California's math assessment items were at Level 1, 26% were at Level 2, and no items were at Levels 3 or 4, and none were open-ended (Yuan & Le, 2012). Zero percent of California students examined using the state's math achievement tests provided for the study were assessed on levels of higher cognitive demand (Yuan & Le, 2012). Increasing cognitive alignment should include rewriting some assessment items to other than a multiple format, consideration of expanding or eliminating the timed element of the assessment, and/or administering an adaptive ELM. It must be noted that Yuan and Le (2012) used too few reviewers to ensure reliability; however, the findings are consistent with similar research. In a study of 138 standards-assessment pairs, Polikoff, Porter, and Smithson (2011) found only half of the standards content to be assessed in the test items, half of the test content to be covered in the standards, and cognitive dissonance between the assessments and standards. The Yuan and

Le (2012) study should be repeated with at least six, and preferably eight to 20 reviewers, as the Webb (1997, 1999, 2002) protocol recommends.

**Research question 3.** *What is the alignment between the breadth of knowledge of the standards and the assessment?*

The range of knowledge and balance of representation criteria address this question. As with the categorical concurrence, since the ELM pre-dates the standards, it would not be expected that the assessment does not demonstrate the range of knowledge called for in the standards. As Webb, alt, Ely, & Vesperman (2005) noted, if categorical concurrence is low, meaning that not enough assessment items targeted the content of the standards, it follows that range of knowledge for those standards also would be low. A low range of knowledge would be expected for Geometry and Statistics and Probability, which did not meet the content alignment criterion. Although non-achievement of the criterion was expected, reviewer notes revealed shock at just how little the assessment items covered the span of knowledge in the standards (Appendix I, Notes by Reviewer Report). An additional consideration for non-attainment of the criterion is that standards are broadly written and encompass numerous content dimensions, whereas assessment items are narrowly focused (Porter et al., 2009).

*Steps to improve alignment in range of knowledge*. The criterion requires the assessment to reflect a reasonable amount of the content in the standards, and not just a few aspects, defined as at least half of the objectives within a standard having at least one corresponding assessment item (Bhola et al., 2003). Increasing alignment in categorical concurrence will help increase range of knowledge alignment (Webb, Alt, Ely, & Vesperman, 2005). Targeting half of the objectives in each conceptual category means that at least 16 Number and Quantity objectives, 17 Algebra objectives, 23 Interpreting Functions objectives, 23

Geometry objectives, and 18 Probability and Statistics objectives must have a corresponding assessment item. More succinctly stated, 97 objectives must be targeted by at least one assessment item in order to meet the criterion. Appendix F, the Item Agreement Report, shows the objectives that are inadequately targeted. Some assessment items could be changed to target the objectives, particularly the uncodeable items in Tables 24 and 25, respectively).

*Balance of representation.* The criterion indicates whether the assessment emphasizes one standard over another. As shown in Table 28 (Mean in the Index column under the Balance of Index columns), the objectives under a given standard were emphasized evenly in the assessment items, except for the Number and Quantity standards, whose .6 index value indicated weak alignment and a bimodal distribution of the assessment items. Appendix F, the Item Agreement Report, confirms that the items matched to Number and Quantity standards cluster around Objectives 1.1b (5 matches) and 1.3a (19 matches), and that the items fail to target substantial areas of the category's content.

*Steps to improve alignment in balance of representation*. The Item Agreement Report (Appendix F) shows that the assessment items over-target Algebra objectives. Some items could be changed to target the Number and Quantity standards. If items will be changed to align the range of knowledge criterion, above, care should be taken that the changed items target under-represented objectives (Webb, Alt, Ely, & Vesperman, 2005). Here again, the uncodeable items in Tables 24 and 25 are resources for a pool of items that possibly could be changed.

**Findings in relation to the research literature.** The present study's findings regarding the ELM's content, rigor, and breadth were in line with the research literature that suggests placement tests do not fully measure the knowledge and skills required for college-level, credit-bearing courses (Achieve Inc., 2007). In a content analysis of more than 1,200 math assessment items from samples of national admissions and placement tests most commonly used in open-access two- and 4-year institutions, as well as state and system-wide, and institution-level tests, Achieve (2007) found that 75% of the items measure Algebra, with a heavy emphasis on Pre-algebra. Fewer than one in four items targeted Algebra I and, with few exceptions, less than 30% of the items corresponded to Algebra II. As indicated in the present study, Achieve's (2007) analysis suggested that placement tests do not target the higher cognitive levels. More than three-quarters of the items called for the application of routine procedures to solve problems -- Level 2 knowledge and skills – and only 17% of the items were categorized at Levels 3 and 4. Less than 15% of the items addressed Geometry. Compared internationally, the heavy Pre-Algebra emphasis focuses on content taught in the 9th grade or below in other countries.

**Findings in relation to previous alignment studies.** The current study built on and complements the educational alignment research of Brown and Conley (2007), Brown and Niemi (2007), and Shelton and Brown (2008), among others. All of the studies followed the Webb (1997, 1999) methodology. Brown and Conley (2007) examined the alignment between college readiness standards aligned to select research universities across the country and 30 ELA and 30 mathematics high school assessments from 20 states, excluding California. Brown and Niemi (2007) studied the alignment between placement tests most widely used in California community colleges and the augmented California Standards Test, which includes the Algebra II and Summative High School Mathematics tests and additional items from the CSU Early Assessment Placement test. The math portion of the augmented CST is taken only by students enrolled in Algebra II or a higher level math course, which is only 20% of California's high school students (Brown & Niemi, 2007). Shelton and Brown (2008) evaluated the coherence between community college placement tests and the California Standards Test in General Mathematics, Algebra I, and Geometry, taken by the majority (80%) of California high school students. The present study partially fills the research gap in the analysis of placement tests used in California public colleges and universities by analyzing the alignment between the placement test used in California's broad-access 4-year public university system and the college-ready-aligned Common Core content standards for high school math (grades 9-12).

Consonant with the previous studies, the present study suggested that the alignment between the high school math standards and the ELM test is inconsistent, inadequate, and requires improvement if students are to transition from high school to the university system ready to succeed in entry-level college courses. Similarly, findings from Brown and Conley (2007) indicated that high school assessments assess only segments of the college readiness standards and at the less cognitively complex levels (e.g., computation and mathematical reasoning), leaving some standards grossly underrepresented or unrepresented, as does the ELM. Brown and Conley (2007) asserted that assessments alone cannot measure the content knowledge, cognitive and metacognitive skills central to college success.

Along with finding content alignment in less than half of the topic areas between the augmented CST and community college placement tests, Brown and Niemi (2007) also noted the lack of content mastery by the 20% of students who took the augmented CST in 2006 (5.7% took the Summative High School Math test and 12.3% took the Algebra II assessment). Almost half had not mastered the content sufficiently to reach a basic level of achievement, resulting in a foreseeable high number of students who were assigned to remediation in community college. In contrast, findings from the current study indicate that the Common Core standards cover more topics, a broader range of topics, at a higher cognitive level than the ELM, and that students who complete standards-based courses will master content sufficiently to pass the math placement test and obviate remediation.

While Shelton and Brown's (2008) findings indicated that a quarter of the college placement test content areas were not addressed by any high school objectives, the converse was indicated in the present study, with two-fifths of the high school standards not addressed by the college placement test. Shelton and Brown (2008) found substantial alignment in General Mathematics but not in Algebra I or Geometry. The current study found substantial alignment in Algebra only at the Algebra I level but not at the Algebra II level, and no content alignment in Geometry, although the ELM was designed to assess Algebra II and Geometry proficiencies. As in the current study, Shelton and Brown (2008) indicated the standards were at least or higher in cognitive complexity than the placement tests.

**Unexpected findings underlying the current study.** Validity speaks to whether or not interpretations made from assessment results are appropriate and accurate (Bhola et al., 2003). The present analysis of whether the Common Core high school math standards are aligned with the CSU's Entry-Level Math placement test assumed the ELM is valid for the purposes of predicting the probability of success in credit-bearing, entry-level college math courses, and for accurately placing students into courses based on interpretations of the test results. A review of the 2010 unpublished validity study conducted by ETS, the test co-developer, showed the placement test to have severe error rates in placing students into the entry-level math course most appropriate for their proficiency level (see

Tables 10 and 11, pp. 46-48), relegating the current study to being an analysis of alignment between college-ready standards and a college placement exam shown to be ineffectual for the purpose for which it is used.

The undisclosed validity study findings showed the ELM to be a weak predictor of student success, defined by the CSU as a grade of C or higher, or "Pass" (an unknown distribution of grades A, B, or C). Based on the CSU definition of success, 78% of the 2,852 regularly-admitted students who scored below the cut-score (the bulk of whom score *far below* the cut score), but who took the college-level course despite the remedial recommendation (non-compliant students), were *just as successful*, and in some cases *slightly more successful*, than students who scored above the cut-score and took the college-level course (compliant students) (ETS, 2010). As importantly, the study showed the ELM is an ineffective predictor of students likely to fail. Only 21% of the students predicted to fail the baccalaureate course did so, statistically indistinguishable from the 20% of students predicted to pass the course who also failed it (ETS, 2010).

The ELM validity study finding is consistent with emerging placement test validity studies that indicate severe error rates in student placement (Armstrong, 2000; Scott-Clayton, 2012), and suggest that placement tests are valid predictors of *high performance* (earning a B or better), rather than of *student success* (a C or better, or "Pass"). Factors that contribute to the weakness of placement tests as predictors of student performance include their weak correlation to college grades (Belfield & Crosta, 2012; Roska et al., 2009); the multi-dimensionality of college readiness (Conley, 2003); and the efficacy of remedial programs that result from remedial placement decisions (Attewell et al., 2006; Bahr, 2008; Bettinger &

Long, 2004, 2006; Boatman & Long, 2010; Calcagno & Long, 2008; Martorell & McFarlin, 2010).

***Weak placement test correlation to college grades.*** Placement tests account for only a small variance in college grades and student success rates; thus, are only weakly correlated to course grades (Belfield & Crosta, 2012; Roska et al., 2009).

***The multidimensionality of college-readiness.*** College readiness entails more than just content knowledge, and includes non-content-based thinking skills such as metacognitive learning skills (habits of mind that correlate to the eight Common Core Practice Standards); cognitive strategies; and high school-to-college transition knowledge and skills ("college knowledge"), as Conley's (2007b) expanded operational definition of college readiness describes (see Figure 13). Placement tests are used as the sole measure of college-readiness but assess only content knowledge, only a fraction of the multiple aspects of college readiness. A placement instrument that examines a minority of the required proficiencies is less effectual than the use of a measure or multiple measures that consider and assess the other factors. Research data suggest that grade point average alone, and multiple measures are more effective predictors of student success than are placement tests alone (Belfield & Crosta, 2012; Scott-Clayton, 2012).

***Efficacy of remedial programs.*** Students are placed into remedial programs as a result of decisions made based on placement test results. Research is contradictory and inconclusive regarding the efficacy of remedial programs, as discussed fully in Chapter 1. Bettinger and Long (2004) reminded that the correlation between participation in remediation and lower graduation rates is not causation, and that risk factors common to students placed into remediation, such as academic under-preparation, account for lower graduation rates rather than remediation itself. Similarly, Adelman (1999, 2006) emphasized that high school academic rigor is the strongest predictor of college success.

***Student behavior – Credit/No Credit election.*** Compounding the severe error rate issue is students' election to take the course "Credit/No Credit" as opposed to a letter grade. For unknown reasons, 51% of the 2,852 students who scored below the ELM cut score but ignored the remedial designation and decided to take the baccalaureate-level course, took it "Credit/No Credit." In stark contrast, only 1.5% of the above-cut-score students in the college-level course made the same election. *There was no difference in the passage rate of students in the college-level course who scored above or below the ELM cut score*. Given that 77.8% of the below-cut-score students passed the college-level course, and 77.0% of the above-cut-score students passed but earned a letter grade, the "Credit/No Credit" decision could indicate that being associated with remediation has a stigmatizing or discouraging effect on student confidence, choices, or behavior. The below-cut-score students made decisions that had negative implications on impressions of the student's abilities and the quality of their academic performance. Only letter grades carry credit points toward calculation of grade point average. To the detriment of the 1,454 below-cut-score students who took the baccalaureate course "Credit/No Credit," a "Pass/Credit" earns credit hours that count toward degree completion, but does not earn credit points for computing grade point average. These students thus lost an opportunity to demonstrate their academic achievement, and the CSU lost the opportunity to include the grade points of 1,454 students in its computation of the grades point averages of it students, perhaps suppressing the important indicator of the academic quality of CSU students.

Similar behavior is noted among the above-cut score students who elected to take the remedial course instead of the college-level course. Whereas only 1.5% of above-cut-score students in the college-level course elected to take the course Credit/No Credit, 41% of the above-cut-score students in the remedial course took the course Credit/No Credit. The underlying reasons for the Credit/No Credit election are beyond the scope of this study, but merit further research.

## Conclusion

A panel of high school and higher education math content experts reviewed and discovered partial alignment in the content, cognitive demand, breadth of knowledge between California's Common Core Content Standards for Higher Mathematics (9-12) and the California State University's Entry-Level Mathematics placement test. The math placement test included fewer topics, focused primarily on middle-school-level math skills, and spanned a narrower range of knowledge than did the college-ready Common Core math standards. Consistent with these findings and research literature, an unpublished ELM validity study conducted by the test co-developer (obtained by a Public Records Act request), revealed that the ELM fails to predict student success or failure as defined by the CSU, and has severe error rates in placing students into the appropriate entry-level math course. The ELM is a predictor of students who will perform *best* in the course (distinguishing A, B, and C grades), not students who will *succeed* in the course (when A, B, and C grades are aggregated). The passage rates of above- and below-cut-score students enrolled in the college-level math course without remediation were indistinguishable.

## Recommendations

These findings suggest opportunities to increase the placement test's alignment with the content and cognitive demand of the standards by changing some test items to reflect the content and depth-of-knowledge levels of the standards. The findings also suggest the need for the CSU to re-examine its placement test, policies and practices, including commissioning an independent, third-party validity study, and disseminating the findings, and the means by which it determines college-readiness and the need for remediation.

Findings suggest the following recommendations for research and practice.

**Recommendation #1:**

Repeat the alignment analysis for the Entry-Level Mathematics placement test and Algebra II standards.

**Recommendation #2:**

Repeat the alignment analysis for the Entry-Level Mathematics placement test and sixth, seventh, and $8^{th}$ grade math standards, respectively.

**Recommendation #3:**

Conduct a validity study of the Entry-Level Mathematics placement test to evaluate the accuracy and efficacy of placement decisions made based on the placement test score results, and disseminate the findings.

**Recommendation #4:**

Re-evaluate and redesign the Entry-Level Mathematics placement test to:

- align with the content and cognitive demands of the Common Core Content Standards for Higher Mathematics (9-12);
- a non-timed, or longer-time format;
- be an adaptive test;

- be a diagnostic test beyond the binary college-ready/remedial determination, toward a range of scores to place students whose majors do not require Algebra II into the appropriate entry-level quantitative reasoning course required for the degree.

**Recommendation #5:**

Develop a 12$^{th}$ grade math course to prepare students for college-level math that incorporates the content of CSU remedial courses, modeled on the Early Assessment Program's 12$^{th}$ grade ELA's Expository Reading and Writing Course intervention for 11$^{th}$ grade students who are not ready for college-level courses.

## Implications for Practice

The development, adoption, and implementation of the Common Core State Standards provides the educational system the opportunity to bridge the historical divide between high school and higher education and align fragmented policies to improve student success. Just as the K-12 system included higher education in the development and implementation of the Common Core standards, so should the CSU include other educational sectors in the re-examination and redesign of its math placement test to improve alignment with the standards. One of the benefits of the study's engagement of content experts from the high school, community college, and 4-year university sectors was the opportunity for the sectors to collaborate, discuss, and offer solutions to issues regarding the knowledge and skills students need to be college-ready. As was evident in this and similar alignment studies, the ratings by content experts from different educational sectors regarding specific objectives within standards might vary considerably; however, as Webb et al. (2006) noted, those differences are legitimate differences of perception.

Despite its high-stakes consequences, little is known about the CSU's Entry-Level Mathematics placement test. When the placement test becomes aligned with the standards, high school instructors will not have to decide among teaching to high school graduation standards, college admission standards, or college placement standards. Instead, they will be able to teach to the standards knowing they also are preparing students to be ready for college as measured by the placement assessment, and placed into entry-level college courses.

Utilizing the senior year to focus on preparation for first-year college math preparation will facilitate curricular alignment between the senior year and first year of college, and will impact seniors' 12th-grade course-taking pattern to make substantive progress toward access to college-level courses. Seniors will have information in the senior year regarding the high stakes and consequences of the college placement test which will help them make informed decisions about the courses to take to successfully transition to college-level courses. High school and higher education instructors will collaborate to develop the 12th grade curriculum not only to prepare students be ready for college-level math, but also to link senior-year and first-year college course content to meet the quantitative reasoning requirement. The recommendations have implications for pre-service teacher preparation and in-service development for both sectors, particularly with respect to the development of the 12th-grade curriculum.

These recommendations are suggested to address the causes of college remediation as opposed to treatments for remediation.

## Suggestions for Future Research

Improved alignment between the placement test and standards can be informed by further research on alignment with other system components.

**Recommendation #1:**

Investigate the use of multiple measures, including high school transcripts along with placement test scores, to inform student proficiency for placement decisions.

**Recommendation #2:**

Investigate placing entering students into college-level gateway courses with co-requisite supplemental instruction and academic support services.

**Recommendation #3:**

Investigate the percentage of CSU students assigned to remediation who do not enroll in remedial courses, and the underlying reasons.

**Recommendation #4:**

Investigate the percentage of CSU students who successfully complete remedial courses but who do not enroll in the gateway course within two years, and the underlying reasons.

## Concluding Discussion

Investigations into the causes of the pervasive need for college remediation tend to examine the secondary and postsecondary educational sectors disjointedly, as separate educational systems. The implementation of Common Core and development of standards-aligned assessments are driving new conversations and decisions for improvement both within and among the sectors of the educational system. Not only do the standards present an opportunity for K-12 to increase the rigor of its academic standards so that all students graduate high school ready for college or career, but they also force higher education to examine how its assessment and placement policies and practices impact students' transition from high school to college. The current study investigated remediation through a systems lens focusing on the placement test as the point of alignment between the system components. The family of theories underlying this study set forth that: improvements in one part of the system should result in improvements in the other(s); alignment of the parts should improve efficiencies; scalable, sustained change is directed from a systems level and implemented locally; and policies between the components should be consistent, coherent, logical, and integrated.

The study's findings indicated that students who master the Common Core curriculum will be able to pass the CSU's ELM placement test and enroll in college-level math courses without remediation. The ELM, however, which predates Common Core, must be modified (improved/aligned) to assess Common Core content adequately and to do so at the standards' levels of cognitive demand. In addition to content and cognitive demand, the study illuminated issues with the structure and format of the ELM. The CSU should revisit the 90-minute time-limited format to ensure the ELM is not just a measure of students' test-taking skills under time constraints; rather, that the test provides students sufficient time both to answer all of the assessment items, and to answer them at higher levels of cognitive demand. The CSU also should discuss whether the multiple choice structure lends itself to assessing standards at higher levels of cognitive demand, beyond recall and basic comprehension as the ELM currently assesses.

Beyond issues of adjusting the ELM's content, cognitive demand, format, and structure to align with the Common Core is the fundamental issue of validity. The 2010 validity study's findings that the ELM failed to predict below-cut-score students' success in first-year college-level courses without remediation calls into question the appropriateness of using the ELM for course placement. The finding should compel critical, system-level conversations regarding the ELM's efficacy. The validity study's finding that more than two thousand students, who would have been assigned to remediation based on their placement test scores, were just as successful as students scoring above the cut score, fuels the debate regarding use of placement tests as the sole measure of student placement in college courses. It would appear that the pervasiveness of remediation in the CSU could be due, in part, to the ELM's substantial placement errors. The stakes would appear too high, and the cost of remediation too great, in time to degree; degree completion; student, family, and institutional expense; unrealized income; and stagnant educational attainment, to (continue to) use a placement instrument found ineffective for the purpose of accurate placement.

The CSU is mandated legislatively to assess first-year students' readiness for college-level studies, report to the legislature annually first-time students' reading, writing, and mathematics proficiency, and is required by the Board of Trustees to conduct ongoing placement test validity studies. Since ETS conducted the 2010 study as an unpublished statistical report, it is unclear to whom results are reported. The annual proficiency reports to the legislature do not include validity study findings.

Low college placement test scores and resulting high remediation rates have been cited as evidence that first-year students who are deemed academically unprepared -- many of whom are students of color -- cannot, or will not, perform college-level work; do not belong in a 4-year university; and should be redirected to community college to gain proficiency. Placement tests have been used to keep students out of 4-year institutions, rather than to provide access and additional support to underprepared students. Thousands of first-year CSU students who enrolled directly into college-level math, who were predicted to fail the college-level course, performed indistinguishably from students predicted to pass the course. This validity study finding, if reported, could shift perceptions regarding students deemed remedial, compel independent examination of the ELM, cause a rethinking of the CSU's placement instrument and remedial policies and practices, and lead to improved intersegmental alignment. Kegley and Kennedy's (2002) Report of the California State University Task Force on Facilitating Graduation expressed such a shift clearly:

> In the past it was not uncommon for a new faculty member to emerge from a Ph.D. institution assuming his or her job was to separate wheat from chaff – to reward bright and able students and to weed out those who apparently didn't belong in college. One common indication of this assumption was the "gatekeeper" course, also known as the "flunk out" course, usually the entry-level class in the major, whose job it was to get rid of unworthy to enter the field. Increasingly, this attitude of helping the cream rise to the top has been replaced by a commitment to helping all students master the curriculum. This fundamental rethinking of the role of the teaching faculty has led to many innovations in instruction and assessment. While maintaining rigor and high standards, many faculty members now focus on mastery rather than gatekeeping (p. 5).

The mission of the CSU as a regional comprehensive university is to serve qualified students of the region who aspire to earn a 4-year degree. When students have met the requirements for admission, it is incumbent upon the CSU to ensure that its policies and practices facilitate rather than impede seamless high school-to-college transition, enrollment, academic progress, and timely degree completion.

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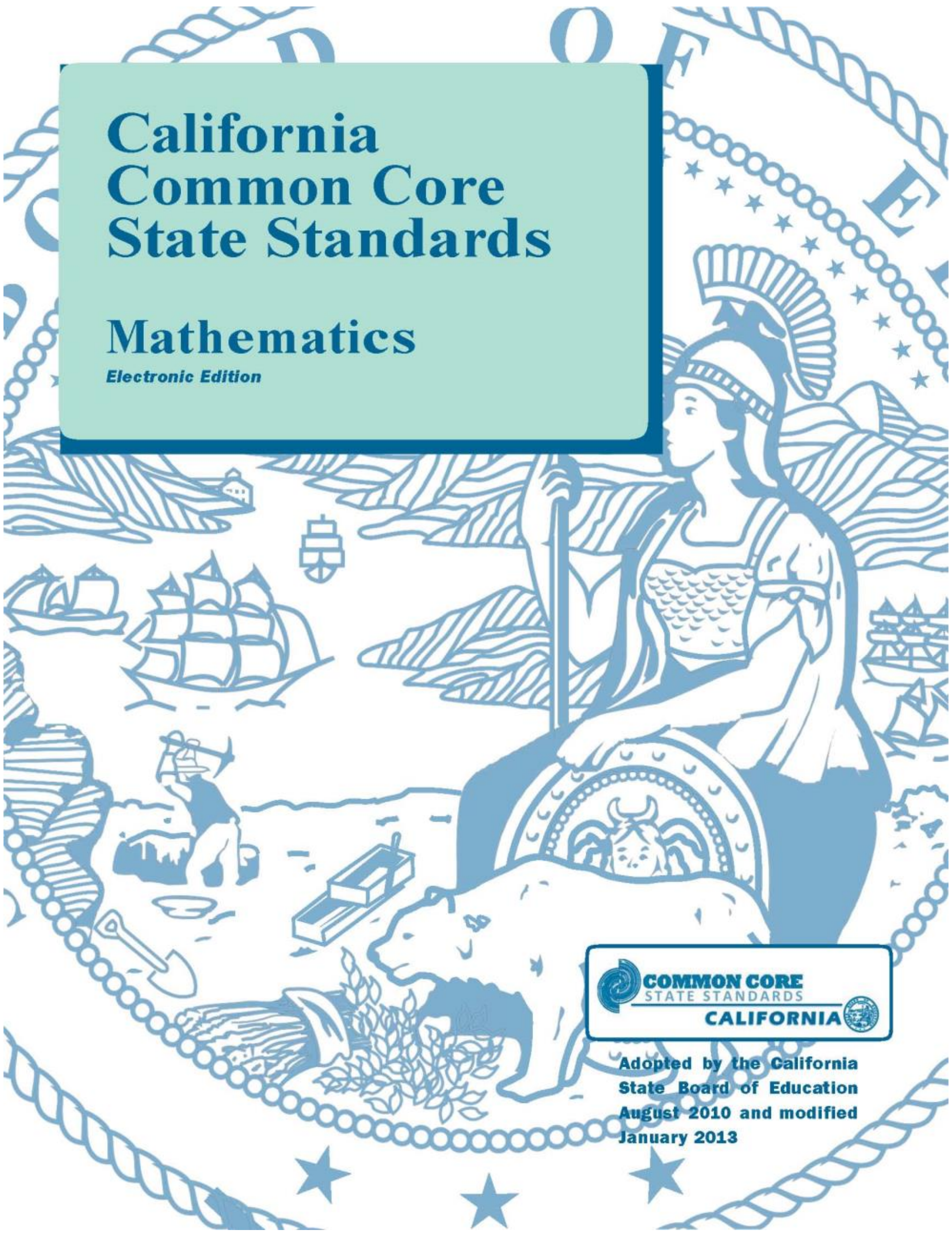
# APPENDIX A: CALIFORNIA COMMON CORE CONTENT STANDARDS FOR HIGHER MATHEMATICS (9-12)



## Publishing Information

Senate Bill 1200, Statutes of 2012, called for modification of the California additions to the Common Core State Standards for Mathematics. The California Common Core State Standards: Mathematics (CA CCSSM) were modified January 16, 2013, following the recommendation of State Superintendent of Public Instruction (SSPI) Tom Torlakson. SSPI Torlakson consulted the Mathematics Curriculum Framework and Evaluation Criteria Committee regarding modifications to the CA CCSSM and the organization of model courses in higher mathematics. SSPI Torlakson and the State Board of Education (SBE) convened two public hearings in order for the field to provide input on the recommended modifications. When the CA CCSSM were modified, the members of the SBE were Michael W. Kirst, President; Trish Boyd Williams, Vice President; Sue Burr; Carl A. Cohn; Bruce Holaday; Josephine Kao; Aida Molina; Patricia Ann Rucker; Nicolasa Sandoval; and Ilene Straus.

Senate Bill 1 from the fifth Extraordinary Session (SB X5 1) in 2010 established the California Academic Content Standards Commission (Commission) to evaluate the Common Core State Standards for Mathematics developed by the Common Core State Standards Initiative for rigor and alignment with the California standards. Based on the evaluation, the Commission inserted words, phrases, and select California standards to maintain California's high expectations for students. On July 15, 2010, the Commission recommended that the SBE adopt the CA CCSSM as amended. The members of the Commission were Greg Geeting, Chair; Heather Calahan; Steven Dunlap; Robert Ellis; Eleanor Evans; Bill Evers; Scott Farrand; Mark Freathy; Lori Freiermuth; Bruce Grip; Kathy Harris; Jeanne Jelnick; Deborah Keys; James Lanich; Matt Perry; Pat Sabo; Brian Shay; Alba Sweeney; Hilda Villarreal Writ; Chuck Weis; and Ze'ev Wurman. Support for the Commission was provided by the Sacramento County Office of Education under the direction of Sue Stickel, Deputy Superintendent of Schools.

When the CA CCSSM were adopted by the SBE on August 2, 2010, the members of the SBE were Theodore Mitchell, President; Ruth Bloom, Vice President; Alan Arkatov; James Aschwanden; Benjamin Austin; Yvonne Chan; Gregory Jones; David Lopez; and Johnathan Williams. Jack O'Connell, former State Superintendent of Public Instruction, is also recognized for his leadership during the adoption of the standards in August 2010.

The *California Common Core State Standards: Mathematics* was edited in part by the staff of CDE Press, with the cover and interior design prepared by Tuyet Truong. It was published by the California Department of Education, 1430 N Street, Sacramento, CA 95814-5901. It was distributed under the provisions of the Library Distribution Act and *Government Code* Section 11096. The Common Core State Standards appear as they were published by the Common Core State Standards Initiative.

The electronic edition of this document is slightly different from the print publication issued by the California Department of Education in 2013; it includes minor text and typographical corrections.



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The full text of the *California Common Core State Standards, Mathematics, Electronic Edition*, can be accessed here: http://www.cde.ca.gov/be/st/ss/documents/ccssmathstandardaug2013.pdf

# APPENDIX B: REVIEWERS' CURRICULA VITAE

**Joseph Robert Fiedler**
Bakersfield, California

EDUCATION:

| | | |
|---|---|---|
| Ph.D. Mathematics | 1988 | The Ohio State University |
| M.S. Mathematics | 1972 | The Ohio State University |
| A.B. Mathematics | 1970 | Harvard College |

FIELDS OF INTEREST:
Mathematics Outreach
Mathematics Pedagogy and Curriculum
Topological Graph Theory

EMPLOYMENT:

| | |
|---|---|
| 9/99 – Present | Professor, Department of Mathematics, California State University, Bakersfield |
| 9/95 – 12/95 | Visiting Associate Professor, Department of Mathematics, The Ohio State University |
| 9/93 – 8/99 | Associate Professor, Department of Mathematics, California State University, Bakersfield |
| 9/89 – 8/93 | Assistant Professor, Department of Mathematics, California State University, Bakersfield |
| 6/89 – 8/89 | Visiting Assistant Professor, Department of Mathematics, The Ohio State University |
| 1/86 – 12/88 | Lecturer and Graduate Teaching Associate, Department of Mathematics, The Ohio State University |
| 9/80 –12/85 | Program Associate and Lecturer, Department of Mathematics, The Ohio State University |
| 9/78 – 12/85 | Lecturer, Department of Mathematics, The Ohio State University |
| 1/73 – 8/78 | Graduate Teaching Associate, Department of Mathematics, The Ohio State University |
| 8/72 – 12/72 | Graduate Research Assistant, Department of Mathematics, University of Victoria |
| 9/71 – 6/72 | Graduate Teaching Associate, Department of Mathematics, The Ohio State University |
| 9/70 – 9/71 | Lecturer, Department of Mathematics, The Ohio State University |

PUBLICATIONS:

- *Statement of Competencies in Mathematics Expected of Incoming College Students*. Intersegmental Committee of the Academic Senates Subcommittee on the Mathematics Competency Statement April 2010

- "Extremal Problems Associated with the Bandwidth of Bipartite Graphs" (with Robert Brigham, Julie Carrington, Ronald Dutton, and Richard Vitray) *Journal of Graph Theory* December 2000 Volume 35 Number 4.
- "Software for Teaching Conservation Biologists: A Review of EcoBeaker 2.0" *Conservation Biology* April 2000 Volume 14 Number 2.
- *Calculus: Mathematics and Modeling, Revised Preliminary Edition* (with W. C. Bauldry, W. Ellis, F. Giordano, P. Judson, E. Lodi, R. Vitray, and R. West) Addison Wesley Longman: 1999.
- *Calculus: Mathematics and Modeling, Revised Preliminary Edition Preview* (with W. C. Bauldry, W. Ellis, F. Giordano, P. Judson, E. Lodi, R. Vitray, and R. West) Addison Wesley Longman: 1998.
- *Students' Solutions Manual for Functioning in the Real World: A Precalculus Experience*, First Edition (with I. Alarcón) Addison Wesley Longman: 1997.
- *Instructors' Solutions Manual for Functioning in the Real World: A Precalculus Experience*, First Edition (with I. Alarcón) Addison Wesley Longman: 1997.
- *Calculus: Mathematics and Modeling,* Preliminary Edition (with W. C. Bauldry, W. Ellis, F. Giordano, P. Judson, E. Lodi, R. Vitray, and R. West) Addison Wesley Longman: 1997.
- *Maple Projects for the Calculus Student: A Tool Not an Oracle,* Second Edition (with W. C. Bauldry) Brooks/Cole: 1996.
  *Instructors' Solutions Manual for Functioning in the Real World: A Precalculus Experience*, Preliminary Edition (with I. Alarcón) Addison Wesley Longman: 1996.
- "Computing the Orientable Genus of Projective Graphs" (with J. P. Huneke, R. B. Richter, and G. N. Robertson) *The Journal of Graph Theory*: November 1995 Volume 20 Number 3.
- "Precalculus with Derive" OSU YSP Pre-12th Grade Curriculum (With Wade Ellis Jr. and Ignacio Alarcón) Manuscript July 1993.
- "Topological Graph Theory" (with Phillip Huneke) Revised OSU YSP Pre-10th Grade Curriculum, Manuscript August 1992; available through Eisenhower National Clearinghouse.
- "Number Theory and Codes" OSU YSP Pre-11th Grade Curriculum, Manuscript August 1992
- *Maple Laboratories for the Calculus Student: A Tool Not an Oracle* (with W. C. Bauldry) Brooks/Cole 1990.
- "Mathematics and the Microcomputer: A New Paradigm" (with W. C. Bauldry) *Proceedings of the Second International Conference on Mathematics Instruction and Technology* October 1989.
- "Maple and the Macintosh" (with W. C. Bauldry) *Centroid – Newsletter of the North Carolina Council of Teachers of Mathematics*: Spring 1989.

WEB PUBLICATIONS:

- *Draft California Mathematics Curriculum Framework*, April 2013. (http://www.cde.ca.gov/be/cc/cd/draftmathfwchapters.asp)
- *Making Educational Policy, California Style:* Lead Article in T[3] Newsletter, December 2008.

WORKSHOPS DELIVERED:

- *Using the TI-73 to Illustrate the CCSS Data and Statistics Strands in Middle School* for KCSOS, Bakersfield, CA: June 24–16, 2014.
  *Introduction to Nspire CX CAS for Preservice Teachers* Bakersfield, CA: June 17–18, 2014.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series L* (with Dr. Mike Lutz, Dr. Tony Alteparkarian, and Ms. Terran Felter of CSUB, Mr. Kyle Atkin of KHSD) Bakersfield, CA: January 7, February 18, March 25, May 6, 2014.
- *Math 523: Geometric Linear Algebra* (Edvention Grant with Ms. Kristi Hatak of KHSD) CSUB, Summer Quarter.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series K* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB, Mr. Andy Hicks of KHSD and Ms. Leah Shields of KCSOS), Bakersfield, CA: September 18, October 23, November 27, 2012; January 25, February 26, March 19, May 7, 2013.
- TI-73 Smartview for Stiern Middle School series II. Bakersfield, CA: September 22, October 27, December 15, 2012; January 12, March 17, May 4, 2013.
- *The California Mathematics Common Core State Standards* as part of CMP STIR Common Core Workshop: August 9, 2012.
  *Using TI-73 Smartview and a Smartboard for Stiern Middle School*, Bakersfield, CA: August 7–8, 2012.
- *Getting Started with Nspire CAS in High School Math*, $T^3$ Short Course. Bakersfield, CA: July 17-19, 2012.
- *The TI-73 as a Demonstration Device in Grades 5–8*, San Luis Obispo, CA.: June 21–22
- TI-73 Smartview follow-up series I. September 10, October 8, November 5, 2011; January 14, February 11, March 17, 2012.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series J* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB, and Mr. Andy Hicks of KHSD), Bakersfield, CA: September 27, October 25, November 29, 2011; January 17, February 21, March 20, May 2012.
- *Using TI-73 Smartview and a Smartboard to Enrich Middle Grades Math*, Bakersfield, CA: August 8–10, 2011.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series I* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB, and Ms. Leah Shields of KHSD), Bakersfield, CA: September 28, October 26, November 16, 2010, January 11, February 15, May 3, 2011.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series H* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB, Ms. Leah Shields and Ms. Margaret DeArmond of KHSD), Bakersfield, CA: September 15, 29, October 20, November 17, 2009: January 12, February 22, April 20. 2010.
- *Hand-held Technology in the Mathematics Classroom*, Project NExT, Portland, OR: August 7, 8, 2009.

- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series G* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB and Ms. Leah Shields of KHSD), Bakersfield, CA: September 16, 30, October 28, November 25, 2008, January 20, February 24, April 28, 2009.
- *Preservice Teacher Education* $T^3$ College Short Course for Desque University, Pittsburgh, PA: October 3–4, 2008.
- *Preservice Teacher Education* $T^3$ College Short Course for BGSU, Bowling Green OH: September 19–20, 2008.
- *Introduction to the TI-73 for Sixth Grade* and *Introduction to the TI-84 for Seventh and Eighth Grade* for Santa Maria-Bonita/Cal Poly SLO Math Science Partnership, San Luis Obispo, CA: August 4–8, 2008.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series F* (with Dr. Mike Lutz and Ms. Terran Felter of CSUB and Ms. Leah Shields of KHSD), Bakersfield, CA: October 2, 23, November 27, 2007; January 15, February 26, April 24, May 13, 2008.
- *Introduction to the TI-73* Pomona Unified School District, Pomona, CA: August 15–16, 2007.
- *Using the TI-73 in Grades 4 – 6* Antelope Valley Math Science Partnership year three workshop, Lancaster, CA: June 27, 2007.
- *Preservice Teacher Education* $T^3$ College Short Course for San Jose State University, San Jose, CA: June 8–9, 2007.
- *TI-73 Workshop* for Bakersfield Mathematics Council, Bakersfield, CA: May 12, 2007.
- *Preservice Teacher Education* $T^3$ College Short Course for CSU Long Beach, Long Beach, CA: April 22, 2007.
- *Preservice Teacher Education* $T^3$ College Short Course for CSU Northridge, Northridge, CA: March 17, 2007.
- *Preservice Teacher Education* $T^3$ College Short Course for CSU Bakersfield, Bakersfield, CA: February 16–17, 2007.
- *Preservice Teacher Education* $T^3$ College Short Course for LA Pierce College, Los Angeles, CA: October 7, 2006.
- *A Functional Approach to Developmental Mathematics* $T^3$ College Short Course for LA Pierce College, Los Angeles, CA: October 6, 2006.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series E* (with Drs. Axelle Faughn and Mike Lutz of CSUB and Ms. Margaret DeArmond of KHSD), Bakersfield, CA: September 19, October 17, 2006, January 25, February 27, May 2, 2007.
- *California Algebra I on the TI-84* $T^3$ Custom Short Course for Tulare County Office of Education Math Science Partnership, Visalia, CA: July 24–28, 2006.
- *Introducing the TI-73 in Grades 4 – 6* Antelope Valley Math Science Partnership year two workshop, Lancaster, CA: June 26–30, 2006.
- *Developmental Algebra Using a Function Approach* $T^3$ College Short Course for Utah Valley State College, Orem UT: May 12–13, 2006.
- *Preservice Mathematics Teachers for High School* $T^3$ College Short Course for UCLA Mathematics Department, Los Angeles, CA: February 11, 2006.

- *Preservice Mathematics Teachers for Middle & High School* $T^3$ College Short Course at Greater San Diego Math Council Annual Meeting, San Diego, CA: February 4, 2006.
- *Developmental Algebra Using a Function Approach* $T^3$ College Short Course for Southwestern College, Chula Vista, CA: December 9–10, 2005.
- *Developmental Algebra Using a Function Approach* AMATYC Traveling Technology Workshop and $T^3$ College Short Course for OKMATYC, el Reno, OK: September 24, 2005.
- *Developmental Algebra Using a Function Approach* $T^3$ College Short Course for Cuyamaca College, El Cajon, CA: August 10–12, 2005.
- *Hand-held Technology in the Mathematics Classroom*, Project NExT, Albuquerque, NM: August 4, 5, 2005.
- *Using Hand-held Technology in the Training of Teachers*, San Diego University/MAA Preparing Mathematicians to Educate Teachers (PMET) Workshop, San Diego, CA: June 30, 2005.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series D* (with Dr. Mike Lutz of CSUB and Ms. Margaret DeArmond of KHSD), Bakersfield, CA: February 15; March 7; April 12; May 17, 2005.
- *APPS on the TI-83 Plus/TI-84 Plus* (with Dr. Mike Lutz and Dr. Janet Tarjan of Bakersfield College) for Bakersfield Mathematics Council, Bakersfield, CA: April 2, 2005.
- *Combined San Jaoquin Valley and Cal Poly SLO/CSU Bakersfield Mathematics Projects Leadership Retreat* (organized with Mrs. Lori Hamada of Fresno County Superintendent of Schools), Three Rivers, CA: January 29 – 30, 2005.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series C* (with Dr. Mike Lutz of CSUB and Ms. Margaret DeArmond of KHSD), Bakersfield, CA: October 26, November 9, December 7, 2004.
- *Introduction to the Graphing Calculator and Data Collection* for Kern County Court and Community Schools, Bakersfield, CA: October 18–19, 2004.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course for Truckee Meadows Community College, Reno, NV: August 20–21, 2004.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course at Santa Ana College, Santa Ana, CA: August 12–13, 2004.
- *Cal Poly SLO/CSU Bakersfield Leadership Institute* (organized with Mrs. Kate Dubost of San Luis Obispo) Los Osos, CA: August 2–7, 2004.
- *Data Collection and Hand-helds* University of San Diego PMET Workshop, San Diego, CA: June 30, 2004.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course for San Diego Mesa College, San Diego, CA: May 14–15, 2004.
- *Kern Union High School District Beginning Teacher Support and Assessment (BTSA) Content Workshop Series B* (with Dr. Mike Lutz of CSUB and Ms. Margaret DeArmond of KUHSD), Bakersfield, CA: February 10, March 9, April 13, May 11, 2004.

- *Combined San Joaquin Valley and Cal Poly SLO/CSU Bakersfield Mathematics Projects Leadership Retreat* (organized with Mrs. Lori Hamada of Fresno County Superintendent of Schools), Three Rivers, CA: January 29 – February 1, 2004
- *Algebra I for Novice Users of Technology Using the TI-73* $T^3$ Short Course for Lancaster City School district, Lancaster, CA: November 12, 19, 2003.
- *Dealing With Data* $T^3$ Workshop, National Alliance of Black School Educators (NABSE) Annual Meeting, Reno, NV: November 15, 2003.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course for Central Wyoming College, Riverton, WY: September 11–13, 2003.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course for Grossmont College, San Diego, CA: August 21–22, 2003.
- *Teaching AP Calculus for Understanding* (with Mrs. Cindy Hendrix of Lancaster High School) Interactive Mathematics Program Professional Development Institute, Oxnard, CA: August 11–15, 2003.
- *Cal Poly SLO/CSU Bakersfield Mathematics Project Geometry Institute* (with Mr. Doug Garber of Liberty High School, and Ms. Kerstin Riggenbach of Paso Robles High School), Los Osos, CA: July 21–25, 2003.
- *Kern Union High School District (KHSD) Beginning Teacher Support and Assessment (BTSA) Content Workshops Series A* (with Dr. Mike Lutz of CSUB and Ms. Margaret DeArmond of KHSD), Bakersfield, CA: February 4, March 4, April 1, May 6, 2003.
- *Cal Poly SLO/CSU Bakersfield Mathematics Project Leadership Retreat* (organized with Mrs. Kate Dubost of San Luis Obispo), Los Osos, CA: May 2–4, 2003.
- *A Functional Approach to Developmental Mathematics* $T^3$ Short Course for Watcom Community College, Bellingham, WA: March 24–5, 2003.
- *Combined San Joaquin Valley and Cal Poly SLO/CSU Bakersfield Mathematics Projects Leadership Retreat* (organized with Mrs. Lori Hamada of Fresno County Superintendent of Schools), Three Rivers, CA: January 31 – February 2, 2003.
- *Teaching AP Calculus for Understanding* Follow-up (with Mrs. Cindy Hendrix of Lancaster High School) Interactive Mathematics Program Professional Development Institute, Oxnard, CA: January 29–31, 2003.
- *Teaching AP Calculus for Understanding* (with Mrs. Cindy Hendrix of Lancaster High School) Interactive Mathematics Program Professional Development Institute, Oxnard , CA: August 12–16, 2002.
- *Cal Poly SLO/CSU Bakersfield Leadership Institute* (organized with Prof. Alan Holtz of CPSU SLO) San Luis Obispo, CA: July 21–27, 2002.
- *Introduction to the TI-89* AMATYC Traveling Technology Workshop, Wichita, KS: April 5, 2002.
- *The TI-89 in Collegiate Mathematics* $T^3$ Custom Short Course, Portland Community College, Portland, OR: March 1–2, 2002.
- *Teaching AP Calculus for Understanding* Interactive Mathematics Program Professional Development Institute, Berkeley, CA: June 18–22, 2001.
- *Using the TI-89 and CBL/CBR in the High School Curriculum*, Kern Educational Partnership Short Course, Bakersfield CA: April 21, 28, May 3, 10, 2001.

- *The TI-89 and TI-92 in Intermediate and College Algebra* $T^3$ Custom Short Course, Portland Community College, Portland, OR: January19–20, 2001.
- *Introduction to the TI-89* San Joaquin Valley Mathematics Project Super Saturday, Fresno, CA: November 18, 2000.
- *College Algebra on the TI-83 Plus*, $T^3$ Custom Short Course, Metropolitan State College of Denver, Denver, CO: August 25–26, 2000.
- *Using Technology to Enhance Middle School Mathematics*, Chipman Jr. High School, Bakersfield, CA, June 26–29, 2000.
- *Calculus: Mathematics and Modeling*, $T^3$ Affiliated Short Course, Prince George's Community College, Largo, MD: May 30–June 2, 2000.
- *Using the TI-89 and CBL/CBR in the High School Curriculum*, Kern Educational Partnership Short Course, Bakersfield CA: April 29, May 6, 13, 20, 2000.
- *Pedagogical Use of Computer Algebra Systems*, Technical Institute of Sophia, Sophia, Bulgaria: April 7, 2000.
- *The TI-89 Across the Curriculum,* $T^3$ Custom Short Course, Valencia Community College, Orlando, FL: June 24–26, 1999.
- *CAS-CALC Technology College Short Course*, Illinois State University, Normal, IL: May 10–14, 1999.
- *Training Faculty for Cross-Disciplinary Calculus-based Modeling Using Hand-Held Technology* (with Mr. Wade Ellis Jr. of West Valley College) Grossmont College San Diego, CA: August 17–19, 1998.
- *Training Faculty for Cross–Disciplinary Calculus–based Modeling Using Hand–Held Technology* (with Mr. Wade Ellis Jr. of West Valley College and Prof. Richard Vitray of Rollins College) Rollins College, Winter Park, FL: August 3–7, 1998.
- *CAS–CALC Technology College Short Course*, Manchester, CN: July 20–22, 1998.
- *PCALC–CALC Technology College Short Course* (with Dr. Sally Thomas of Orange Coast College), Bakersfield College, Bakersfield, CA: March 5–8, 1998.
- *CAS–CALC Technology College Short Course*, Concordia College, Moorhead, MN: June 23–27, 1997.
- *CAS–CALC Technology College Short Course*, North Central University, DeKalb, IL: June 9–13, 1997.
- *Calculus: Mathematics and Modeling Workshop* (with Mr. Wade Ellis Jr. of West Valley College, Prof. Phoebe Judson of Trinity University, and Lt. Col. Rich West of The United States Military Academy) San Antonio, TX: May 27–31, 1997.
- *CAS–CALC Technology College Short Course*, University of Massachusetts, Amherst, MA: June 24–28, 1996.
- *CAS–CALC Technology College Short Course*, William Rainey Harper College, Chicago, IL: June 17–20, 1996.
- *Introduction to Maple*, Naval Postgraduate School, Monterey, CA: June 15, 1994.
- *Maple in the Mathematics Classroom*, California Polytechnic State University, San Luis Obispo CA: March 31, 1994.
- *Student Maple in the Undergraduate Curriculum*, California Lutheran College, Thousand Oaks, CA: Oct. 7, 1993.
- *Derive in Developmental Mathematics* (with Mrs. Niki Shaw of CSUB), Los Pasedos College, Livermore, CA: September 10, 1993.

- *Derive in Intermediate Algebra* (with Mrs. Niki Shaw of CSUB) Delta College, Stockton CA: May 6, 1993.
- *Computer Algebra Systems in Graduate Mathematics Education* (with Mr. Wade Ellis of West Valley College) CSU San Marcos, San Marcos, CA: May 28, 1993.
- *Calculus Reform and Computer Algebra Systems* (with Mr. Wade Ellis of West Valley College) Fort Lewis College, Durango CO: June 21–26, 1992.
- *Calculus Reform and Computer Algebra Systems,* (with Mr. Wade Ellis of West Valley College) St. Mary's College of California, Moraga CA: December 13–15, 1991.
- *Calculus Reform and Computer Algebra Systems* (with Mr. Wade Ellis of West Valley College) West Valley College, San Jose CA: June 16–22, 1991.
- *Calculus Reform and Computer Algebra Systems* (with Mr. Wade Ellis of West Valley College) Mississippi State University, Starkville MS: June 17–22, 1990.

CONFERENCE PRESENTATIONS:

- Poster Session: *"California Mathematics Project Supporting Teachers to Increase Retention (CMP STIR) at CSU Bakersfield: The University Model of Support"*. Mathematics Teacher Retention Symposium. Los Angeles, CA: March 22–24, 2012.
- *Mathematical Competencies Expected of Entering College Students*. CMC–N Annual Conference, Monterey, CA: December 2–4, 2011.
- *Graphing Calculators Before Graphing*, $T^3$ International, San Antonio, TX: February 25–27, 2011.
- *The Case for CAS*. GSDMC Annual Conference, San Diego, CA: February 5, 2011.
- *Mathematical Competencies Expected of Entering College Students*. GSDMC Annual Conference, San Diego, CA: February 5, 2011.
- *The Case for CAS*. GSDMC Annual Conference, San Diego, CA: February 4, 2011.
- *Mathematical Competencies Expected of Entering College Students*. CMC–S Annual Conference, Palm Springs, CA: November 5-6, 2010.
- *Modeling Real World Data With a CAS: Learning About Rates*, TODOS–$T^3$ Regional Conference, Bakersfield, CA: September 10–11, 2010.
- *Refresh your knowledge of the TI-84 OS*, $T^3$ International Conference, Atlanta, GA: March 4–7, 2010.
- *Teaching Fractions on a Large Screen Calculator* $T^3$ International Conference, Seattle, WA: February 26–March 1, 2009.
- *Teaching Fractions on a Large Screen Calculator* Greater San Diego Math Council Annual Meeting, San Diego, CA: February 6–7, 2009.
- *The Case for CAS-Capable Calculators* California Math Council Central Section Algebra Symposium, Seaside, CA: March 7-8, 2008.
- *Using APPS on the TI-73* Teachers Teaching With Technology 20th International Conference, Dallas, TX: February 28–March 2, 2008.
- *Mini–PTE High School Workshop* Greater San Diego Math Council Annual Meeting, San Diego, CA: February 1–2, 2008.
- *Bringing the TI-73, a Large Screen (not necessarily graphing) Calculator Into Your Classroom* $T^3$ International Conference, Chicago, IL: March 8–11. 2007.

- *Now that we have them, what can we do with symbolic calculators?* Exploring Math and Science with Technology, $T^3$ Regional, HCTM, and PiMATYC Conference, Honolulu, Hawai'i: January 23–24, 2007.
- *Data, Difference, and Differential Equations*, $CMC^3$ Annual Meeting, Monterey, CA: December 1, 2006.
- *Exploring the TI-89, a Handheld Computer Algebra System*, Project ACCCESS workshop at AMATYC 32nd Annual Conference, Cincinnati, OH: November 4, 2006.
- *Getting Started with the TI-84 in Developmental Algebra,* Commercial Presentation at American Mathematical Association of Two-Year Colleges (AMATYC) 32nd Annual Conference, Cincinnati, OH: November 4, 2006
- *Using a Large-screen Calculator in Grades 4–8* California Math Council –Far North Annual Meeting, Arcata, CA: October 21, 2006.
- *Almost a Tricorder: Using the TI-84 and the EasyData APP* ICTCM, Orlando, FL: March 17–18, 2006.
- *Using the TI-73, CBL2, and Navigator in the Middle Grades Classroom* (with Ms. Monica West of Emerson Middle School and Mr., Ray O'Brien of Philadelphia) $T^3$ International Conference, Denver, CO: February 23–26, 2006.
- *A Master of Arts Program for Middle and High School Teachers* Joint Mathematics Meetings, San Antonio, TX: January 12–15, 2006.
- *Wireless Communication for Middle Grades* (with Ms. Sarah McKendry of Emerson Middle School) California League of Middle Schools Technology Conference, Monterey, CA: November, 18–19, 2005.
- *Data, Differences, and Differential Equations: Newton's Cooling Law* AMAYTC Annual Meeting, San Diego, CA: November 10–13, 2005.
- *A University-Middle School Collaboration: Report from the Field* $T^3$ International Conference, Washington, DC: March 18–20, 2005.
- *Meet the TI-73, the Middle Grades Graphing Calculator* Greater San Diego Math Council Annual Meeting, San Diego, CA: February 4–5, 2005.
- *A Life In Mathematics as a professor of Mathematics* (Keynote address to the inaugural class of ACCESSS Fellows) AMATYC Annual Meeting, Orlando, FL: November 18–21, 2004.
- *Transformational Graphing on the TI-83 Plus* Mount Lassen Mathematics Symposium, Anderson, CA: March 27, 2004.
- *From Data to Differential Equation with a CAS: Not the Way Newton did it!* Chico State Mathematics Department Colloquium, Chico, CA: March 26, 2004.
- *Modeling with Difference Equations* $T^3$ Conference and Professional Development Institute, New Orleans, LA: March 11-14, 2004
- *Making Sense of Conic Sections* $CMC^3$-S Anaheim, CA March 6, 2004.
- *What are APPS Doing on My Calculator?* AMTE, San Diego, CA: January 23, 2004.
- *Using a Graphing Calculator and Functional Approach in Developmental Mathematics* Pathways Through Algebra, San Diego, CA: January 15, 2004.
- *Integrating a Hand-held CAS into an Master of Arts "Geometric Linear Algebra"* MAA Joint Winter Meetings, San Diego, CA: January 10, 2004.

- *Modeling with Difference Equations: An Alternative to College Algebra* Workshop, AMATYC Annual Meeting, Salt Lake City, UT: November 13–16, 2003.
- *Graphing Calculators and Data Collection in Calculus and Below* Project NExT Short Course at MAA Math Fest, Boulder CO: July 31–August 1, 2003.
- *Meet the Middle Grades Graphing Calculator* (with Dr. Roger Peck of CSUB) Math Science & Technology Conference, Bakersfield CA: March 22, 2003.
- *Technology: A Tool for Understanding* California Math Council Central Algebraic Thinking Symposium Grades 4–6 Strand, Seaside CA: March 15, 2003.
- *Algebra Capable Calculators: Taming the Beast* California Math Council Central Algebraic Thinking Symposium Grades 8–12 Strand, Seaside CA: March 15, 2003.
- *Parametric Conics with a CAS* $T^3$ International Conference, Nashville, TN: March 7-9 2003.
- *Math Teachers without Math: Responses to the Challenge* AMS/MAA Winter Meetings, Baltimore, MD: January 15–18, 2003.
- *TI-73: The Middle Grades Graphing Calculator* California Math Council North, Monterey, CA: December 7, 2002.
- *An Interactive Approach to College Algebra Using TI-83+ APPS* (for Prof. Patsy Fagan of Drake University) ICTCM 15, Orlando, FL: November 2, 2002.
- *Interventions that Work*, (with Prof. Kim Flachmann) Hispanic Association of Colleges and Universities (HACU) annual meeting, Denver CO: October 28, 2002.
- *Calculus on the TI-89 and Voyage 200* (Industry Sponsored) $CMC^3$ South Mini-Conference; Mira Mar College, San Diego, CA: October 5, 2002.
- *What are "Flash Applications" Doing on My Calculator and What Good Could They Possibly Do Me?* (Industry Sponsored Workshop) $CMC^3$ Annual Meeting; Monterey, CA: December 6–8, 2001.
- *A CAS Approach to Conics* $CMC^3$ Annual Meeting; Monterey, CA: December 6–8, 2001.
- *Modeling in Precalculus with Algebra Capable Calculators* International Conference on Technology in Collegiate Mathematics XIV, Baltimore, MD: November 2–5, 2001.
- *From Prealgebra to Precalculus: Using the TI-89* (with Mr. Wade Ellis Jr. of West Valley College) Teachers Teaching with Technology 10th International Conference, Columbus OH: March 15-18, 2001.
- *Introduction to Derive* (with Prof. Carl Leinbach of Gettysberg College) Teacher Teaching with Technology Profession Development Conference, Columbus OH: March 13-14, 2001.
- *Graphing Calculators for the Middle Grades: the TI-73* Math, Science & Technology Conference, Bakersfield, CA: February 24, 2001.
- *Not Just for AP Calc: Symbolic Calculators in Prealgebra and Beginning Algebra* California Mathematics Council -- Northern Section Annual Meeting, Asilomar, CA: December 1–3, 2000.
- *Silencing the California Mathematics Standards* (with Ms. Margaret De Armond of Kern High School District) California Mathematics Council -- Northern Section Annual Meeting, Asilomar, CA: December 1–3, 2000.

- *Was Galileo Right? Taking Modeling Beyond Curve Fitting* (with Mr. Wade Ellis Jr. of West Valley College) American Mathematical Association of Two-Year Colleges, Chicago, IL: November 9–12, 2000.
- Project NExT Workshop: *Teaching Mathematics with Technology* MAA Math Fest, Los Angeles, CA: August 3–4, 2000.
- *Modeling in Calculus: From Difference to Differential Equations* (with Mr. Wade Ellis Jr. of West Valley College) NCTM Annual Meeting, Chicago, IL: April 13–16, 2000.
- *"May you live in interesting times." Ancient Oriental Curse or Twenty-first Century Blessing?* 29th Spring Conference of the Union of Bulgarian Mathematicians, Lovetch, Bulgaria: April 3–6, 2000.
- *Modeling with Difference Equations in Precalculus Algebra* (with Mr. Wade Ellis Jr. of West Valley College) $T^3$ International Conference, Dallas, TX: March 18, 2000.
- *Free $$$ to Study Math* (with Ms. Margaret De Armond of Kern County Superintendent of Schools) Math, Science & Technology Conference, Bakersfield, CA: February 26, 2000.
- *Getting a Mathematics Department Involved in Middle Grades Mathematics: A California Case Study* AMS/MAA Winter Meetings, Washington, DC: January 20, 2000.
- *Modeling in Calculus: Difference and Differential Equations* (with Mr. Wade Ellis Jr. of West Valley College) American Mathematical Association of Two-Year Colleges, Pittsburgh, PA: November 18–21, 1999.
- *Iterative Algebra* (for Professor Emeritus Kurt Kreith of UC Davis) American Mathematical Association of Two-Year Colleges, Pittsburgh, PA: November 18–21, 1999.
- *Modeling in Calculus: Difference and Differential Equations* (with Mr. Wade Ellis Jr. of West Valley College) ICTCM 12, Burlingame, CA: November 4–7, 1999.
- *Meet* TI Interactive!: *A Computer Algebra for the Rest of Us* ICTCM 12, Burlingame, CA: November 4–7, 1999.
- Reports: *Status of Kern English and Math Precollegiate (KEMP) Program* and *Progress of the Kern County Joint Articulation Taskforce* Third CSUB/BC/KHSD Articulation Day; Bakersfield, CA: April 30, 1999.
- *AP Calculus and the TI-89* (with Mr. Wade Ellis Jr. of West Valley College) NCTM Annual Meeting, San Francisco, CA: April 23, 1999.
- *Using the TI-89 to Construct Mathematical Models* $CMC^3$ – South Annual Meeting, Costa Mesa, CA: March 19, 1999.
- *Meet the New TI-89* Math, Science Technology Conference; CSUB, Bakersfield, CA: 27 February, 1999.
- *Differential Equations, Calculus, and the TI-89* (with Mr. Wade Ellis Jr. of West Valley College) $T^3$ Conference; Chicago, IL January 22–25, 1999.
- *Use of the New TI-89 Calculator in Calculus* (with Mr. Wade Ellis Jr. of West Valley College) California Mathematics Council –- Northern Section Meeting; Asilomar, CA: December 4–6, 1998.

- *What to do with Hand-Held Computer Algebras? A New Approach to Calculus* (with Mr. Wade Ellis Jr. of West Valley College) CMC$^3$ Annual Meeting; Monterey, CA: December 4–6, 1998.
- *Mathematical Modeling in Calculus* (with Prof. Bill Bauldry of Appalachian State University) ICTCM 11; New Orleans. LA: November 19–21, 1998.
- *Differential Equations on the TI–89* (with Prof. Bill Bauldry of Appalachian State University) ICTCM 11; New Orleans, LA. November 19–21, 1998.
- *Calculus and Mathematical Modeling on the TI-92 Family* (with Mr. Wade Ellis Jr. of West Valley College) American Mathematical Association of Two-Year Colleges Annual Meeting; Portland, OR: November 5–8, 1998.
- *Hand–held Computer Algebra Systems in the High School Calculus Classroom* California Math Council –Central Section Meeting (with Prof. Roger Peck of CSU Bakersfield) Fresno, CA: October 17, 1998.
- *The New Statement on Competencies and Entry Level Mathematics Examination* Second CSUB/BC/KHSD Articulation Day; Bakersfield, CA: March 27, 1998.
- *Calculus in Light of a Hand–held CAS* (with Mr. Wade Ellis of West Valley College), Teachers Teaching with Technology 10; Nashville, TN: March 13–15, 1998.
- *Integrated Technology for Integrated Curricula* (with Prof. Becky Larson of CSUB) 7th Math, Science & Technology Conference; Bakersfield, CA: February 21, 1998.
- *The TI-92: An Integrated Technology for Integrated Curricula*, California Mathematics Council -— Northern Section Annual Meeting; Asilomar, CA: December 6–8, 1997.
- *Calculus on the TI–92* (with Mr. Wade Ellis of West Valley College) American Mathematical Association of Two Year Colleges Atlanta, GA: November 13–17, 1997.
- *Differential Equations on the TI–92 Family* (with Prof. Bill Bauldry of Appalachian State University) ICTCM 10; Chicago, IL: November 6–9, 1997.
- *Introduction to the TI–92* (with Prof. Rebecca Larson of CSU Bakersfield) California Mathematics Council – Central Section Meeting; Fresno, CA: October 18, 1997.
- *New Developments in Hand–held Computer Algebra Systems*, (Invited Presentation) MAA Pacific Northwest Section Meeting; Bellingham WA: June 19, 1997.
- *The TI–92 and Calculus* (with Mr. Wade Ellis of West Valley College) Teachers Teaching with Technology 9; Philadelphia, PA: February 9, 1997.
- *Calculus on the TI–92* and *Calculus: Mathematics and Modeling* (with Prof. Bill Bauldry of Appalachian State University, Mr. Wade Ellis of West Valley College, and Prof. Rick Vitray of Rollins College) ICTCM 9 Reno NV: November 10, 1996.
- Project NExT Workshop: *Changing Paradigms: Technology and Pedagogy* (with Mr. Wade Ellis of West Valley College) AMS/MAA Summer Meeting, Seattle WA: August 10-11, 1996.
- *The TI–92: Computer Algebra for Everyone* (with Mr. Wade Ellis of West Valley College) Teachers Teaching with Technology 8; Jacksonville, FL: March 16, 1996.
- *Freshman Mathematics with the TI–92* (with Mr. Wade Ellis of West Valley College) ICTCM 8; Houston TX: November 18, 1995.

- *Freshman Mathematics with a Handheld C. A. S.* (with Mr. Denny Bruzynski of West Valley College) American Mathematical Association of Two Year Colleges Annual Meeting, Little Rock AK: November 9, 1995.
- *Introduction to the TI–92* Fall Meeting of the Association of Minority Engineering Program Administrators; Columbus OH: October 19, 1995.
- *Derive and Developmental Mathematics* (with Mrs. Niki Shaw of CSUB) AMS/MAA Summer Meeting, Burlington VT: August 7, 1995.
- *Projective Planar Graphs of Representativity Four*, AMS Southeast Section Meeting, Orlando, FL: March 17, 1995.
- *Calculus Reform: a Local Status Report* (with Mrs. Maria Griggs of Bakersfield South High School) Bakersfield Math Science Technology Conference: Bakersfield, CA March 4, 1995.
- *The Ohio State University Young Scholars Program Pre–twelfth Grade Computer Algebra Systems* (with I. Alarcón of CSUB, and W. Ellis of West Valley College), AMS/MAA Winter Meetings, San Francisco CA: January 5, 1995.
- *Derive in Elementary and Intermediate Algebra Workshop*, National Council of Teachers of Mathematics Regional Conference, San Francisco CA: February 24, 1994.
- *Maple in the Calculus Curriculum,* American Mathematical Association of Two Year Colleges Annual Meeting, Boston, MA: November 18, 1993.
- *Maple in the Calculus*, California Calculus Consortium, San Luis Obispo CA: June 4–6, 1993.
- *The Second Time Around With Technology: Tutorial vs. Tool*, National Council of Teachers of Mathematics National Conference, Seattle, WA: March 31, 1993.
- *Calculator and Computer Graphing: Now That We See the Picture, What Do We do With It?* NCTM Regional Conference, Las Vegas, NV: February 24, 1993.
- *The Use of Derive in Intermediate Algebra* (with Ms. Nomiki Shaw of CSUB) $CMC^3$ Annual Meeting, Monterey CA: December 3, 1992.
- *A Report on the Use of Derive in Business Analysis at CSUB*, California Calculus Consortium, San Luis Obispo CA: May 11, 1991.
- *Maple Workshop* (with Prof. W. Bauldry of Appalachian State University) ICTCM 3, Columbus OH: November 10, 1990.

CONFERENCE ROUNDTABLES

- Panelist: *Introducing the California Mathematics Framework*, CMC-North Annual Meeting, Asilomar, CA: December 6–8, 2013.
- Panelist: *Introducing the California Mathematics Framework*, CMC-South Annual Meeting, Palm Springs, CA: November 1–3, 2013
- Panelist: *News from the California Framework Committee*, Plenary session at the UCLA Mathematics Department 2013 Curtis Center Mathematics and Teaching Conference, Los Angeles, CA: March 2, 2013.
- Panelist: *Technology in the Classroom: The perspectives from the University and the High Schools*, Math Teacher Retention Symposium 2012, Los Angeles, CA: March 22-23, 2012.

- Panelist: *SAT Subject Tests™ in Math: Complementing AP Math*, AP Annual Conference, San Francisco, CA: July 20-24, 2011.
- Panelist: *Deciding How to Teach*, Project NExT, Albuquerque, NM: August 2, 2005.
- Organizer and Panelist: *Extending Your Calculator: APPS on the TI–84*, 17th International Conference on Technology in Collegiate Mathematics, New Orleans, LA: October 28–31, 2004.
- Panelist, *An International Model of Professional Development*, NCTM 82nd Annual Meeting, Philadelphia, PA: April 22–24, 2004.
- Panelist, *What's New in College Algebra and Precalculus Courses*, MAA Math Fest, Boulder, CO: August 2, 2003.
- Panelist, *US and East European Problem Solving in High School Algebra*, NCTM 81st Annual Meeting, San Antonio, TX: April 9–11, 2003.
- Panelist, *Summary Discussion*, Mathematics Education and Mathematics in the 21st Century Conference, Tucson, AZ: February 20–22, 2003.
- Panelist, *Responses to: "Building and Maintaining an Exemplary Teacher Preparation Program within a Department of Mathematics"* Mathematics Education and Mathematics in the 21st Century Conference, Tucson, AZ: February 20–22, 2003.
- Panelist, *Finding Out What Your Students Have Learned* Project NExT, MAA Math Fest, Los Angeles, CA: August 2, 2000.
- Organizer, *The Cross Roads Document* AMS/MAA Winter Meetings, Baltimore, MD: January 8, 1998.
- Panelist, *Future Directions for Calculus* ICTCM 9 Reno NV: November 8, 1996.
- Panelist, *Precalculus Reform* Fifth Annual Conference on the Teaching of Mathematics, San Jose,m CA: June 24, 1995.
- Panelist, *Perspectives on Service Courses for Business*, AMS/MAA Winter Meetings, San Francisco, CA: January 15, 1991.
- Panelist, *Teaching Assistants and Adjunct Instructors*, AMS/MAA Winter Meetings, Anaheim, CA: January 8, 1985.

ON–SITE COURSES

- Mathematics 201 (Calculus I) and Mathematics 202 (Calculus II) for Bakersfield South High School $MS^3$ Academy: AY 2000–01.
- Mathematics 201 (Calculus I) and Mathematics 202 (Calculus II) Bakersfield South High School $MS^3$ Program: AY 1998–99.
- Mathematics 202 (Calculus II) Bakersfield South High School $MS^3$ Program (with Mr. Ignacio Alarcón): Spring Semester 1997.
- Mathematics 201 (Calculus I) and Mathematics 202 (Calculus II) for *Science/Math Pre–engineering Curriculum* ($MS^3$) Bakersfield South High School: AY 1994–95.

IN–SERVICE PRESENTATIONS AND WORKSHOPS

- Choosing a CCSS Curriculum for KHSD Math Chairs: March 15, 2013.
- CA Math Framework: Building Bridges for KCSOS: March 11, 2013.
- CCSS & CA Math Framework in Grades 6-8 for KCSOS: January 23, 2013.
- CCSS & CA Math Framework for KHSD Math Chairs: November 20, 2012.

- The CA CCSS and *Mathematical Competencies Expected of Entering College Students,* for KHSD Math Department Chairs: May 17, 2011.
- *Introducing the New Statement on Competencies in Mathematics Expected of Entering College Freshmen* at SJVMP and CPSUSLO/CSUB Leadership Retreat: Three Rivers, CA, January 28–30, 2011
- *Introducing the New Statement on Competencies in Mathematics Expected of Entering College Freshmen* to California Mathematics Project Directors' Meeting, El Segundo, CA: October 8, 2010.
- *Introducing the New Statement on Competencies in Mathematics Expected of Entering College Freshmen* to KHSD Math Department Chairs, Bakersfield, CA: September 7, 2010.
- *Early Assessment Program Mathematics In-service Parts A & B* (with M. DeArmond & K. Hill of KHSD, G. Robledo of Golden West HS, and Catena Rojas of Highland HS) Bakersfield, CA: March 5 & 27, 2007.
- *EETT Classroom Support Series* for Sequoia and Emerson Middle Schools, 6th grade, Bakersfield, CA: November 7, 8, 14, December 12, 19, 20, 2006, February 6, 13, 14, March 20, May 15, 2007.
- Collecting Environmental Data Workshop for Myrtle Avenue School 6th Grade Teachers, Lamont City School District, Lamont, CA: October 19, 2006.
- *EETT TI-*73 *Workshop* for Emerson and Sequoia Middle Schools 6th grade Teachers, Bakersfield, CA: September 27, 2006.
- *EETT Supplemental Mathematics In-service* for Emerson Middle School Summer Session, Bakersfield, CA: June 13–15; 19–22, 2006.
- *EETT Mathematics Workshop Series* for Emerson and Sequoia Middle Schools 8th grade Math & Science Teachers, Bakersfield, CA: January 24, February 16, May 18, 2006.
- Excel™ Workshop for Myrtle Avenue School 6th Grade Teachers, Lamont City School District, Lamont, CA: April 6, 2006.
- *EETT Mathematics Workshop Series* for Emerson and Sequoia Middle Schools 7th grade Math & Science Teachers, Bakersfield, CA: January 23, February 14, March 7, 2006.
- *Early Assessment Program Mathematics In-service Parts A & B* (with J. Dirkse of CSUB, M. DeArmond & K. Hill of KHSD, G. Robledo of Golden West HS, and Catena Rojas of Highland HS) Bakersfield, CA: January 18, February 2, 2006.
- *EETT Mathematics Workshop Series* for Emerson and Sequoia Middle Schools 7th & 8th Grade, Bakersfield, CA: Oct. 4, November 1, December 13, 2005.
- *EETT Science Workshop Series* for Emerson and Sequoia Middle Schools 7th & 8th Grade, Bakersfield, CA: October 3, 31, December 12, 2005.
- *Early Assessment Program Mathematics In-service Parts A & B* (with J. Dirkse of CSUB, M. DeArmond & K. Hill of KHSD, G. Robledo of Golden West HS, and Catena Rojas of Highland HS) Bakersfield, CA: November 17, December 7, 2005.
- *Antelope Valley Math Science Partnership TI-73 In-service*, Lancaster, CA: October 28, 2005.
- *Cabri Jr.* (with Dr. Mike Lutz) Oxnard Union High School District, Oxnard, CA: April 26, 2005.

- *TI-73 EETT Inservice Workshop Series* Emerson Middle School 7th Grade, Bakersfield, CA: September 29, November 3, December 8, 2004, January 11, February 8, April 5, 2005.
- *TI-73 EETT Inservice Workshop Series* Sequoia Middle School 7th Grade, Bakersfield, CA: September 30, November 4, December 9, 2004, January 12, February 9, March 9, 2005.
- *Data Collection and Analysis with the TI-83 Plus, CBR and CBL2* (with Mr. German Robledo of Golden West HS) for Bakersfield College/Delano HSD Eisenhower grant, Bakersfield, CA: July 10, 2004.
- *Intro to the TI-73* (with Dr. Mike Lutz and Mrs. Angela Pendergrass) Taft High School, Taft, CA: June 7–10, 2004.
- *TI-73 Gear UP! Inservice* Mountain View Middle School, Lamont, CA: September 5, October 3, 2003, February 6, April 16, May 21, 2004.
- *Algebra I for Novice Users of Graphing Calculators Follow-up II* Lancaster City School District, Lancaster, CA: April 13, May 12, 2004.
- *Using the TI-89 in Elementary Algebra*, Oxnard Union School District, Oxnard, CA: November 25, 2003.
- *The TI–73 in Middle School Prealgebra and Algebra GEAR UP Partnership*, Mountain View Middle School, Lamont, CA: May 23, 2003.
- *Geometers' Sketchpad* (with Dr. David Gove), Delano, CA: May 9, 2003.
- *Introducing the TI-89* Oxnard Union School District, Oxnard, CA: February 25, 2003.
- *Lists and Data Collection with the TI-83 Plus II* (with Dr. Mike Lutz) Bakersfield College/Delano High School Eisenhower Grant, Bakersfield College; Bakersfield, CA: 23 November, 2002.
- *Using the TI-73 in the Middle Grades* The Viewpoint School, Calabasas, CA: November 13, 2002.
- *Data Collection with the TI-83 Plus I* (with Dr. Mike Lutz) Bakersfield College/Delano High School Eisenhower Grant, Delano High School; Delano, CA: September 20, 2002.
- *Connecting Math and Science* (with Ms. Margaret De Armond of KHSD) Bakersfield College/Delano High School Eisenhower Grant, Delano, CA: March 13, 2002.
- *Introducing the TI-89* Oxnard Union School District, Oxnard, CA: February 26, 2002.
- *Meet the Middle Grades Graphing Calculator: The TI-73* Bakersfield Mathematics Council/UC Merced Workshop Series, Bakersfield, CA February 5, 12, 19, 2002.
- *TI-89 and AP Calculus* Kern County Superintendent of Schools AP Vertical Integration Project, Bakersfield, CA: February 25, 2002.
- *Uses of Technology in Teaching Mathematics* Kern County Court and Community Schools Mathematics Class Study Group, Bakersfield, CA: October 25, 2001.
- *AP Vertical Integration Workshop* (Mathematics Facilitator with Ms. Margaret De Armond of Kern County High School District) Kern County Superintendent of Schools, Bakersfield, CA: October 19, 2001.
- *Introduction to the TI-73* Mountain View Middle School, Lamont, CA: May 12, 2001.
- *The California High School Exit Exam* Lamont Unified School District, Lamont, CA: February 3, 2001.

- *The California High School Exit Exam* (with Ms. Margaret De Armond of KHSD) Wasco Union High School, Wasco, CA: December 11, 2000.
- *TI-89 – The Algebraic Symbolic Calculator* Bakersfield Mathematics Council Workshop Series, Bakersfield, CA: October 4, 11, & 18, 2000.
- *The Entry Level Mathematics (ELM) Examination* South High School, Bakersfield, CA: August 23, 2000.
- *The Entry Level Mathematics (ELM) Examination* Centennial High School, Bakersfield, CA: May 24, 2000.
- *Technology in Algebra Instruction* Kern County Superintendent of Schools Algebra Articulation Day, Bakersfield, CA: May 18, 2000.
- *The Entry Level Mathematics (ELM) Examination* East Bakersfield High School, Bakersfield, CA: March 29, 2000.
- *The Entry Level Mathematics (ELM) Examination* West High School, Bakersfield, CA: February 23, 2000.
- *The Entry Level Mathematics (ELM) Examination* Stockdale High School, Bakersfield, CA: February 9, 2000.
- *Introduction to the TI-92 Plus in High School Mathematics* Mojave High School, Mojave, CA: January 15 & 29, 2000.
- *Teaching to Mathematics Standards Across the Curriculum* Mojave High School Professional Development Day, Mojave, CA: October 30, 1999.
- *The Entry Level Mathematics (ELM) Examination* Ridgeview High School, Bakersfield, CA October 19, 1999.
- *Introduction to the TI-89* Interactive Mathematics Project TOPS Workshop; Sausalito, CA March 5, 1999.
- *Look What's Happened to the Graphing Calculator* San Joaquin Valley Mathematics Project Lecture Series; Highland High School, Bakersfield, CA: December 8, 1998.
- *The New Entry Level Mathematics (ELM) Examination and Statement on Mathematical Competencies* Arvin High School; Arvin, CA: January 11, 1998.
- *Introduction to the TI-92*, William Taft High School Faculty Day, Cincinnati OH: May 6, 1996.
- *The TI–82 in the High School Curriculum* (with Dr. Janet Tarjan of Bakersfield College) Bakersfield Mathematics Council, Bakersfield, CA: April 23, 1994.
- *Introduction to the Computer Algebra System Derive* (with Mr. Bernie Scanlon of Bakersfield College) Kern High School District, Bakersfield, CA: March 5, 1994.
- *Introduction to the* Computer Intensive Algebra *Curriculum* (with Mr. Ignacio Alarcón of CSUB) Kern High School District, Bakersfield, CA: Oct. 19, 1993.
- *Derive in High School Mathematics*, Bakersfield South High School, Bakersfield, CA: Oct. 5, 1993.
- *Introduction to the TI-81* Garces High School, Bakersfield CA: Feb. 20, 1992.

CONTRACTS

- College Board: SAT Item Review (Content) for CCSS Rewrite: August – December, 2014.
- College Board: SAT Subject Matter Tests in Mathematics: July, 2009 – June, 2015.

- California Department of Education: Content Expert for Math Adoption Review, June, 2013–June 2014.
- Mathematical Accuracy Check for *Bellman et. al: Algebra II* for Pearson Publishing: March–April 2009.
- Lead Article for $T^3$ Newsletter, December 2008.
- TI-TODOS Seventh Grade Mathematics Technology – English Language Learner writing group. June 11–15, 2007 and sequel.
- Manage Middle Grades Teacher Retention (Math 251, 252, 253, 254) for Bakersfield City School District. January – November, 2007.
- Preliminary Transcript Evaluation and Teacher Consultation for Palmdale School District, March, 2006.
- Organize (with Charles Hoffman of Lasalle University, retired) contributed paper session at 2004 MAA Winter Meeting, "Focus on Integrating Graphic Handhelds into Collegiate Mathematics," Texas Instruments.
- Review of geometry manuscript, Key College Press: April 2003.
- Editor for web–based Graphing Calculator Tutorials in support of Washington and Allyn: *Basic Technical Mathematics*, Addison–Wesley Longman: November 1999–February 2000.
- Evaluator for American Mathematical Association of Two Year Colleges–NASA Modules on Applications of Mathematics: 1997.
- Co-author: *Calculus: Mathematics and Modeling*. Addison Wesley Longman: 1996.
- Co-author: Instructors' and Students' Solutions Manuals for *Functioning in the Real World: A Precalculus Experience, First Edition.* Addison Wesley Longman: May–October 1996.
- Co-author: Problem answer section for *Functioning in the Real World: A Precalculus Experience, First Edition*. Suffolk Community College and Addison Wesley Longman: February–April 1996.
- Review of *Solving Differential Equations with Maple V* for Brooks/Cole 1996.
- Review of *A Lab Manual for Calculus with Derive* for McGraw-Hill 1996.
- Developmental Reviewer for Stewart: *Calculus: A Conceptual Approach*, Brooks/Cole 1995–96.
- Co-author: Solutions Manuals and Answers Section for *Functioning in the Real World: A Precalculus Experience, Preliminary Edition*. Suffolk Community College and Addison Wesley Longman: April–December 1995.
- Consultant to the Developmental Mathematics Program for the College of Letters and Sciences and the Department of Mathematics, University of Wisconsin at Whitewater: April 23–25, 1995.
- Review of Viglino & Berger: *Precalculus in Light of Technology*, PWS 1994.
- Review of Jaisingh: *Precalculus Experiments with DERIVE*, PWS 1994.
- Review of DERIVE Lab Manual, West Educational Publishing 1993.
- Review of Calculus manuscript and proposal, West Educational Publishing 1993.
- Review of Precalculus proposal, West Educational Publishing 1993.
- Review of *Applied Mathematics*, Brooks/Cole 1992.
- Review of calculus manuscript, Wadsworth Publishing 1992.
- Review of Algebra and Trigonometry manuscripts, Richard D. Irwin, Inc. 1992

- Review of Stroyan: *Calculus the Language of Change* for Academic Press 1991.
- Review of *Cabri Geometré II* Brooks/Cole 1991.
- Review of Instructors' Manuals for Harris: *Technical Mathematics*, HBJ 1990.
- Review of Harris: *Technical Mathematics*, Harcourt Brace Jovanovich 1989.
- Developmental Review of *Cabri Geometré*, Brooks/Cole 1989.

EXTERNAL GRANT PARTICIPATION:

- Director and Principal Investigator: California Math Project NCLB10 grant ($22,500) 2013-14.
- Director and Principal Investigator: CMP STIR subgrant Year 5 augmentation ($43,000) 2012.
- Director and Principal Investigator: California Math Project NCLB9 grant ($22,500) 2012-13.
- Director and Principal Investigator: California Math Project NCLB8 grant ($29,700) 2011-12.
- Director and Principal Investigator: Cal Poly SLO/CSU Bakersfield Mathematics Project (University of California Office of the President: $18,300 annually) 2011–14.
- Director and Principal Investigator: California Math Project NCLB7 grant ($29,700) 2010-11.
- Director and Principal Investigator: California Math Project NCLB6 grant ($29,700) 2009-10.
- Director and Principal Investigator: California Math Project NCLB–X grant ($18,300) –replacing year 1 funds from CMP08 – 2008-09.
- Director and Principal Investigator: Cal Poly SLO/CSU Bakersfield Mathematics Project (University of California Office of the President: $18,300 annually) 2008–11.
- Director and Principal Investigator: California Math Project NCLB5 grant ($27,000) 2008-09.
- Manager: High School Teacher math course component of Chevron Math-Science grant ($59,000) 2008–09.
- Director and Principal Investigator: California Math Project NCLB–S grant ($20,000) 2008.
- Manager: Middle and High School Teacher math course component of Chevron Math-Science grant ($75,000) 2007–08.
- Director and Principle Investigator: California Math Project NCLB4 grant ($25,200) 2007-08.
- Director and Principal Investigator: CSU Bakersfield STIR (Teacher Quality Enhancement) sub-grant (California Postsecondary Education Commission: $398,000) 2007–2011.
- Manager: Teacher Recruitment and Student Support grant ($60,000) to Bakersfield City School District (California Department of Education) 2006–07.
- Director and Principal Investigator California Math Project NCLB3 grant ($11,200) 2006-07
- Director and Principal Investigator California Math Project NCLB2 grant ($16,000) 2005-06

- Director and Principal Investigator: Cal Poly SLO/CSU Bakersfield Mathematics Project (University of California Office of the President: $62,600) 2005–08.
- Director and Principal Investigator California Math Project NCLB grant ($21,600) 2004-05
- Co-Principal Investigator: Cal Poly/CSUB Mathematics Project CMP02 (University of California Office of the President: $216,000) 2002–05.
- Consultant: *We are the GEAR UP Generation* (United States Department of Education) 2002–05.
- Principal Investigator: *KEP Mathematics Professional Development Institutes* (University of California Office of the President: $ 200,900) 2001–03.
- Co–Director: *Kern Mathematics Preparation Initiative* (California State University Chancellor's Office, Mathematics Preparation Initiative: $98,000) 1999.
- Consultant: *Kern Educational Partnership* (California State University Chancellor's Office, California Academic Partnership Initiative: $778,000 annually) 1999–03.
- Higher Education Partner: *Bakersfield West High School California Academic Partnership Program* Planning & Implementation Grants (California State University Chancellor's Office) 1998–03.
- Higher Education Partner: *Mojave High School California Academic Partnership Program* Planning & Implementation Grants (California State University Chancellor's Office) 1998–03.
- Founding Director: *CSUB Mathematics Tutorial Center* Department of Education Title III Grant (United States Department of Education, Title III) 1998–2001.
- Technology Consultant: *Chipman Junior High School Middle School Demonstration Project* (University of California Trustees, Middle School Demonstration Program) 1998–01.
- Co–sponsor: Kern County Superintendent of Schools MATH COUNTS grant (California Department of Education) 1998–01.
- Consultant: *Training Faculty for Cross–Disciplinary Calculus–based Modeling Using Hand–Held Technology* Undergraduate Faculty Enhancement, (National Science Foundation, Faculty Enhancement Program) 1998–99.
- Higher Education Partner: *$MS^3$ South High School Science/Math Pre–engineering Curriculum*, (California Department of Education, Specialized Secondary Program) 1992–95.
- Consultant: *Partnership to Improve Teacher Competencies in Mathematics* Delano High School (California Postsecondary Education Commission Dwight D. Eisenhower Mathematics and Science Education Grant) 1990.

SPONSORED STUDENT PRESENTATIONS:

- Ricardo Garza: *Integral Closures* CSUB Student Research Competition (2nd place Physical and Mathematical Sciences): March 24, 2003.
- Michael Lazarev: *Newton's Method and Wells of Convergence*, Southern California MAA Section Meeting: March 6, 1993.
- Jeffery Wise: *Curves of Constant Width*, Southern California MAA Section Meeting: March 7, 1992.

PANELS AND BOARDS, PROFESSIONAL SERVICE:

- Member: Smarter Balanced Achievement Level Setting In-Person Panel Grade 11 Math: October 13 – 20, 2014, Dallas, TX.
- Member: CCTC/Pearson Evaluations Math CSET Item Review Panel: February 21, 2014, Web-based.
- Reviewer: *Illustrative Math Project* (http://illustrativemathematics.org/) from 2012 – present, Web–based.
- Member (Chair from Summer 2012): College Board Development Panel for SAT Math Level 1 and 2 Achievement Tests, (Fall and Spring Meetings): Fall 2009 – present, Princeton, NJ.
- Content Expert for 2013 Primary Instructional Materials Review for the California State Board of Education: June – September, 2013, Sacramento, CA.
- Member: CSET Objective Review Conference, Sacramento, CA: February 5, 2013.
- Mathematics Curriculum Framework and Evaluation Criteria Committee, California Department of Education: July 2012–February 2013, Sacramento, CA
- Panelist: California Commission on Teaching Credentials CSET Item Review, Sacramento, CA: December 12–13, 2011: January 30, 2012.
- Content Expert for 2012 Supplemental Instructional Materials Review for the California State Board of Education, March – September 2012.
- Panelist: California Commission on Teaching Credentials Initial (Subject Matter Waiver) Program Review, Sacramento, CA: July, 22-3, 2010 *et seq*.
- Member: CSET: Mathematics Item Review Panel, April 29, 2009.
- Co-Chair: Intersegmental California Academic Senates Subcommittee on Mathematical Competency Statements (Charged with revising the 1997 *Statement on Mathematical Competencies Expected of Incoming Freshmen*) 2008–2010.
- Member: MAA James J. Leitzel Lecture Speakers Committee, 2007 – 2012.
- Member: Bakersfield City SD Algebra Textbook Selection Committee, 2006.
- Member: Single Subject Waiver Program Review Panels for California Commission on Teacher Credentialing, 2005–2007.
- External Reviewer, Promotion and Tenure Committee for the Department of Mathematics University of Minnesota at Duluth, Fall 2005.
- External Reviewer, Promotion and Tenure Committee for the Department of Mathematics San Diego State University – Imperial Valley Campus, Fall 2004.
- Panelist, College-Level Examination Program (CLEP) Precalculus Web Based Standard-Setting, March–April, 2005.
- Panelist, California High School Exit Exam (CAHSEE) Standards Setting Panel, Sacramento, CA: September 18–20, 2003
- Panelist, California High School Exit Exam (CAHSEE) Item Content Review Panel, Sacramento, CA: August 6–7, 2003.
- Member, Best Practices in Education *International Algebra Problem Writing Contest* 2003.
- Referee, *College Math Journal* 2003–04.
- Member, Steering Committee for *Bakersfield College – Delano High School Partnership Grant* Eisenhower Program: 2002–04.

- Member, Advisory Committee for *California's Outstanding Mathematics Educators Outreach Network, COME ON!* (NSF Teacher Enhancement): 2002– 05.
- Member, NCTM *Mathematics Teacher* Teacher Advisory Panel (TAP): 2001–02.
- Referee, *Journal of Online Mathematics and Applications* (*JOMA*): 2001–02.
- Member, AMATYC INPUT (INnovative Programs Using Technology) Award Committee: 2000, 2001, 2002, 2003.
- Member, California Math Council Central Section Executive Committee: 2000–02.
- Member, Bakersfield Math, Science & Technology Conference Steering Committee: 1999–2002.
- Reader, Advanced Placement Calculus Examination: 1998, 1999, 2000.
- Member, Bakersfield Mathematics Council (BMC) Executive Board: 1998–2002. Interim President BMC: November 2000– April 2002.
- District Coordinator: *San Joaquin Valley Mathematics Project* 1999–00.
- Referee: *AMATYC Review*: 1998–2006.
- Member, *San Joaquin Valley Mathematics Project* Steering Committee 1997–99.
- Member, CSUB/BC/KHSD Joint Assessment and Articulation Taskforce 1996–97.
- Member, Advisory Board, Project INPUT (INnovative Programs Using Technology), Annenberg/PBS Foundation and NSF grants to Central Michigan University: 1996–98.
- Member, NSF Site Visit for South Dakota Statewide Systemic Initiative, Pierre, SD: June 25–28, 1995.
- Member, NSF Site Visit for American Indian Center of Central California Rural Systemic Initiative, Auberry, CA: March 19, 1995.
- Member, NSF Rural Systemic Initiative Grant Proposal Evaluation Panel, Washington, DC: April 13, 1995.
- Member, NSF Site Visit for Virginia Statewide Systemic Initiative, Roanoke and Richmond, VA: March 28 – 30, 1995.
- Member, NSF Site Visit for North Carolina Statewide Systemic Initiative, Raleigh, NC: February 15–17, 1995.
- Evaluator for MAA Subcommittee on Mini-courses: Interactive Mathematics Text Project: *Geometer's Sketch Pad*, Seattle, WA: December 3–5, 1993.
- Chair, MAA Subcommittee on Service Courses 1995–1998.
- Member, MAA Subcommittee on Service Courses 1992–1998.
- Member, ICTCM Program Committee 1992, 93, 94, 95, 98, 99, 2000, 02, 03, 04, 05, 06, 07.
- Member, $MS^3$ Bakersfield South High School Specialized Secondary Program and Academy Coordinating Committee 1992–2000.
- Member, NSF Calculus Initiative Evaluation Panel, Washington DC: March 21–22, 1991.

SELECTED MEETINGS:

- Educators Evaluating Quality Instructional Products (ACHIEVE: The American Diploma Project), Washington, DC: May 23–25, 2012.
- TI Nspire–CAS pre-release training, Dallas, TX: November 16–18, 2006.
- NCTM National Meeting, Anaheim, CA: April 6–9, 2005.

- California Mathematics Project *English Learners in Mathematics* Symposium, Los Angeles, CA: May 19–20, 2004.
- *Intersegmental Major Preparation Articulated Curriculum* (IMPAC) Southern Region Meeting, Los Angeles, CA: February 28, 2004.
- *USA–Eastern Europe High School Algebra Symposium* (sponsored by Best Practices in Education) Sosopol, Bulgaria: 23–31 August, 2002.
- *Focus on Algebraic Thinking: Pre–K to 12* (4–6 Strand) California Mathematics Council Central Section Symposium, San Luis Obispo, CA: October 19–20, 2001.
- *The Future of Precalculus*, Arlington, VA: 4–6 October, 2001.
- *USA–Eastern Europe High School Algebra Symposium* (sponsored by Best Practices in Education) Sinaia, Romania: 6–15 August, 2001.
- *A. E. Ross Summer Program Reunion/Conference*, Columbus, OH: July 27-29, 2001.
- *Intersegmental Major Preparation Articulated Curriculum* (IMPAC) Central Region Meeting, Bakersfield, CA: February 24, 2001.
- *Building Bridges to Algebraic Thinking: Pre–K to 12* (4–6 Strand) California Mathematics Council Central Section Symposium, San Luis Obispo, CA: October 20–21, 2000.
- *AVID Tutor Training* Kern County Superintendent of Schools, Bakersfield, CA: September 15, 16, October 13, 14, 2000.
- *Teachers Teaching with Technology Professional Development Conference Workshop*. Irving, TX: February 4–6, 2000.
- *Building Bridges to Algebraic Thinking: Pre–K to 12* (9–12 Strand) California Mathematics Council Central Section Symposium, San Luis Obispo, CA: October 15–16, 1999.
- *USA–Bulgaria High School Mathematics Forum* (sponsored by Best Practices in Education) Bankia, Bulgaria: 8–15, August, 1999.
- *Teachers Teaching with Technology Professional Development Workshop*. Dallas, TX: July 9–12, 1998.
- *Teachers Teaching with Technology Professional Development Workshop*. Irvine, TX: January 24–27, 1997.
- *Revitalizing the Mathematics and Engineering Curriculum with Computer Algebra Systems*: Rose–Hulman Institute of Technology, Terre Haute, IN: July 10–15, 1995.
- *CSU/K–12 Linkage*: CSU San Marcos: May 5–6, 1995.
- Texas Instrument TI–92 Pre–Introduction Consultants' Workshop, Fort Worth, TX: January 27–29, 1995.
- *Functioning in the Real World* Math Modeling/Precalculus Workshop, Suffolk Community College, Long Island, NY: June 10–11, 1994.
- *Differential Equations as a Laboratory Course*: C•ODE•E Workshop, West Valley College, San Jose, CA: June 7–9, 1994.
- *Writing Across the Curriculum*: California State University Faculty Workshops, CSU Bakersfield: February & April, 1994.
- *April Dialogue with NSF and NIH on Undergraduate Research*, Washington, DC: April 16–17, 1993.
- *Calculus From the Graphical, Numerical, and Symbolic Points of View* Workshop, St. Olaf College, Northfield, MN: July 26–31, 1992.

- *Use of Symbolic Computation in Undergraduate Mathematics*: Denison College, Granville, OH: June 26, 1992.
- *Using Knot Theory in Undergraduate Teaching*, CSU Fullerton, Fullerton, CA: April 15–17, 1992.
- *Calculus in Context* Workshop, Occidental College, Pomona, CA: March 25–28, 1992.
- *TEXPrep Dissemination Workshop*, San Antonio, TX: February 6–7 1992.
- *Graph Minors*, AMS–IMS–SIAM Research Conference in the Mathematical Sciences, University of Washington, Seattle, WA: June 22–25, 1991.
- *Topological Graph Theory*, Stowe, VT: June 27–30, 1990.
- *Increasing Minority Participation in Math–Based Disciplines*, California Polytechnic State University, Pomona, CA: March 29–31, 1990.

AWARDS AND HONORS:
- 2007 California Mathematics Council 19th Annual "Ed Begel Memorial Award" for Service to the California Mathematics Community
- 2002 Bakersfield Math Council "Teacher of the Year"
- 1997 CSUB STAAR Booster
- 1995–1996 CSUB Sabbatical Year
- 1993 Ohio State Young Scholars Program 10th Grade Program, "Favorite Teacher"
- 1993 CSUB STAAR Booster
- 1992 CSUB Educational Support Services Outstanding Faculty

Internal Grants
- 2002 CSUB Student Research Scholar Award for Mr. Ricardo Garza ($2000)
- 2002 CSUB Teaching and Learning Center grant for *America Counts* calculators ($500)
- 2001 CSUB Teaching and Learning Center grant for *America Counts* calculators ($500)
- 1996 CSUB Technology Grant (with Dr. Laird Taylor and Mr. Ignacio Alarcón) ($10,000)
- 1990 CSUB University Research Council Mini-Grant ($2500)
- 1990 CSUB Instructional Technology and Development Grant ($1000)

SERVICE AT CSUB:
Department:
- 2001–present: Founding Graduate Program Coordinator
- 1990–present: Mathematics Department Advisor
- Member: Department ASC I Hiring Committee
- 2014: Chair, Department Market Salary Adjustment Committee
- 2014: Chair, Department Chair Review Committee
- 2013–14: Contributor, Q2S Program and Course Conversion
- 2013: Chair, Post Tenure Review Committee
- 2011-12: Contributor, Mathematics Program Periodic Review
- 2011: Member, Department Chair Review Committee

- 2010: Member, Adjunct Lecturer Qualifications Review Committee
- 2010, 12: Member, Mathematics Lecturer Ranking Committee (Layoffs)
- 2007, 08, 10, 11, 12, 13: Mathematics Lecturer Review Committees
- 2002–2010: Founding Chair, Graduate Studies Committee
- 2000–02: Author & Manager, Master of Arts in Teaching Mathematics proposal
- 1999, 00, 01, 02, 04, 08, 09: Member, Post–Tenure Review Committees
- 1999–2001: California Faculty Association (CFA) Departmental Representative
- 1996–98: Member, Colloquium Committee
- 1994–95, 1997–03, 05–07, 08–09, 2013: Member, Mathematics Unit Retention, Tenure, and Promotion (RTP) Committees
- 1992–95, 96–02: Founding Coordinator, Department Calculus Placement Exam
- 1992–94: Chair, Mathematics Department Program Review Committee
- 1991–2001: Member (Founding Chair 1991–00) Student Awards and Honors Committee
- 1991–95: Member, Mathematics Single Subject Competency Panel
- 1990, 91, 93, 98, 99, 01, 02, 05: Member, Faculty Search Committees
- 1990, 91, 92, 93, 2000: Founding Advisor & Coach, Mathematics Contest in Modeling Teams
- 1990–93: Founding Faculty Advisor, CSUB MAA Student Chapter

College:

- 2001–2010: California Faculty Association (CFA) School Representative
- 2004–2007: Math & Computer Science Building Committee
- 2000–01: Founding Chair, Natural Sciences & Mathematics Curriculum Committee
- 1999–2003: Evaluator for Single Subject Mathematics Subject Matter Competency Waiver
- 1997–2002: CSUB Honors Faculty Mentor to Ms. Brooke Ashby
- 1994, 95: Member, Arts & Science Outstanding Graduating Senior Selection Committee
- 1992, 93, 94, 95: Reader, Arts & Sciences Dean's Award for Outstanding Student Papers
- 1992–95: CSUB Merit Scholar Faculty Advisor
- 1990–92: Member, (Chair, 1991–92), Arts & Sciences Curriculum Committee

University:

- 2011–present: Member, University Strategic Planning and Budget Advisory Council
- 2009–present: Member, Teacher Education Advisory Council
- 2008, 2009, 2010, 2011, 2012, 2013, 2014: Member, Summer Academic Senate
- 2008–10, 2011–2103, 2014–present: Chair, Budget and Planning Committee
- 2008–10, 2011–2013, 2014–present: Member, Academic Senate Executive Committee
- 2008–10, 2011–2013, 2014–present: Member, Campus Master Plan Committee
- 2007–2013, 2014–present: At-large Member, Academic Senate
- 2014: Member, GRaSP ASC II Hiring/Interview Committee
- 2013–2014: Member, Taskforce on Use of Indirects from Contracts and Grants
- 2013–2014: Member, Antelope Valley Campus Taskforce II
- 2009–11: Member: Budget Prioritization Task Force

- 2009-10: Member, School of Arts & Humanities Founding Dean Search Committee
- 2009: Member, PPI Committee for Director University Counseling Center
- 2008–10: Member, President's Budget Advisory Council
- 2008–10: Member, Strategic Planning Steering Committee (WASC CPR)
- 2008–10: Member, Strategic Planning Workgroup: Community Engagement (WASC RPC)
- 2008: Secretary, Academic Senate
- 2008: Member, Assistant VP, Institutional Research, Planning, and Assessment Search
- 2007–2013: Founding Member, Pre-baccalaureate Studies Committee
- 2007: Member, Year Round Operations Taskforce
- 2007: Member, *Foundations of Excellence*, Faculty Strand Taskforce
- 2006-07: Member, CFA Strike Committee
- 2006–08: Chair, Faculty Affairs Committee
- 2006–08: *Ex officio* Member, Academic Senate Executive Committee
- 2006–08: Member, Associate Vice President for Academic Affairs Search Committee
- 2006: Member, Department of Modern Languages Post-Tenure Review Committee
- 2005–2013: Founding Member, Early Assessment Program (EAP) Steering Committee
- 2005–2006: Founding Member, Campus Enrollment Policy Group
- 2004–2006: Member, University Program Review Committee
- 2004: Member, Department of English Post-Tenure Review Committee
- 2004: Member, Associate Vice President, Antelope Valley Regional Center Search Committee
- 2003–05: Member, Title V Coordinating Committee
- 2002: Founding Member, University Council
- 2001: Member, CSUB *Bakersfield Vision 2020* Response Team
- 2000–2011: Member, Combined Summer Programs Coordinating Committees
- 2000–02: Founding Faculty Liaison, *America Counts* Tutoring Program
- 2000–01: Member, Search Committee: Dean of Natural Sciences, Mathematics & Engineering
- 1998-03: Member, Title III Coordinating Committee
- 1998–2001: Founding Director, CSUB Mathematics Tutorial Center
- 1997–2001: CSUB Academic Performance Team Mathematics Representative
- 1997: Interim Member, General Education Advisory Committee
- 1996–2001: Member, Graduate Equity Review Committee
- 1996–2000: Mathematics Liaison, Kern English and Math Precollegiate Program (CSU PAD)
- 1996–99: Sponsor, CSU Forgivable Loan for Dr. Sophia Raczowski (Ph.D. 1/99)
- 1994–95, 99–02, 2004–05, 2008–2013: Member, Budget and Planning Committee
- 1994–95: Member, University Planning for Change Task Force
- 1994–95: Chair, University Library, Media, and Computer Services Advisory Committee
- 1992–93: Member, University Academic Affairs Committee
- 1991–95, 96–2001: General Studies Fellow (Freshman Advisor)

- 1991–95, 97: Educational Opportunity Program Faculty Interviewer

Community

- 2011–2012: Member: Palmdale Aerospace Academy Technical Advisory Committee
- 2008–2010: Consultant: Kern County Superintendent of Schools Math Teacher Recruitment.
- 2007–2008: Member: Bakersfield City School District 8th Grade Textbook Adoption Committee.
- 2005–present: Consultant: Palmdale City School District Mathematics Subject Matter Authorization Project.
- 1998, 99, 2000, 02, 05: Judge/Referee, Kern MATH COUNTS.
- 1990, 91, 95, 97, 2001, 06: Grader/Proctor/Judge, CSUB Math Field Day.
- 1999, 2000: Grader, BMC Junior High School Math Olympics.
- Judge, Kern County Science Fair: 1993, 94, 99.
- Organizer/Instructor, West HS STARS: *Mathematics as a Laboratory Science*: 1992–94.

PROFESSIONAL AFFILIATIONS:

American Mathematical Association of Two Year Colleges Member from 1984
AMATYC Traveling Technology Workshop Instructor 2002–07
American Mathematical Society Member 1985–2000
Association for Women in Mathematics Member 1982–2010
Bakersfield Mathematics Council (BMC) Member from 1989
California Association of Math Teacher Educators Member 2006–present
California Faculty Association Member 1990–present
California Mathematics Council Member from 1997
California Mathematics Council of Community Colleges Member from 1993
Greater San Diego Mathematics Council Member from 2005
Mathematical Association of America Member from 1973
National Council of Teacher of Mathematics Member from 1997
Project NExT Advisor 96, 00, 02, 03, 05, 08, 09, 11 cohorts
SoftWare House (Derive) Consultant 1994–99
Texas Instruments Consultant 1994–present
Teachers Teaching with Technology Instructor 1996–present
Waterloo Maple Software Consultant/Ambassador 1993–2000
California Community College Mathematics Instructor Credential #10967
Project NExT Consultant to Dr. Perla Meyers (2000) of the University of San Diego.
Project NExT Consultant to Dr. Lily Khadjavi (2000) of Loyola Marymount University.
Project NExT Consultant to Dr. Michael Fisher (2002) of Fresno State University.
Project NExT Consultant to Dr. Barbara Boshmans (2003) of the University of Rhode Island.
Project NExT Consultant to Dr. Min-Lin Lo (2005) of CSU San Bernardino.
Project NExT Consultant to Dr. Nicole Engelke (2008) of CSU Fullerton.
Project NexT Consultant to Dr. Steven Greenstein (2011) of University of the Virgin Islands.

THE OHIO STATE YOUNG SCHOLAR PROGRAM:

- Summer 1995: Pre–12th grade (Precalculus with Derive) Lead teacher
- Summer 1994: Mathematics Program Coordinator, Pre–12th grade (Precalculus with Derive) Instructor, Post–12th grade Mathematics Elective (Reform Calculus) Developer & Instructor, Pre–9th grade (Probability) Coordinator
- Summer 1993: Mathematics Program Coordinator, Pre–11th grade (Number Theory) Coordinator, Pre–12th grade (Precalculus with Derive) Instructor & Co–author, Pre–10th grade (Topological Graph Theory) Instructor & Author
- Summer 1992: Mathematics Program Coordinator, Pre–11th grade (Number Theory) Author, Coordinator & Instructor, Pre–7th grade (Pre–Algebra) Instructor
- Summer 1991: Mathematics Program Coordinator, Pre–9th grade (Probability) Coordinator & Instructor, Pre–7th grade (Prealgebra) Instructor
- Summer 1990: Computer Work Shop Coordinator, Pre–9th grade (Probability) Coordinator & Instructor, Pre–8th grade (Spatial Visualization) Instructor
- Summer 1989: Pre–8th grade (Spatial Visualization) Instructor

THE OHIO STATE ARNOLD E. ROSS SUMMER PROGRAM

I attended this nationally known Mathematics Summer Program as a participant in the summers of 1965 and 1966. During the summers of 1967 through 1970 I worked as a peer counselor in the Program. My duties initially included tutoring and grading support for the core Number Theory and second year Logic courses. Ultimately, I assumed administrative duties and was encouraged to offer a Moore method course in point set topology for the second year participants. After moving to Ohio State in 1970, I continued my involvement with the program throughout the following decade. Initially I read and evaluated applications. Later, as Manager I was responsible for the administrative and managerial tasks associated with an eight week residential program – including housing, insurance, transportation, classroom space and coordination with the peer counselors. In 1980 I lead a Number Theory Problem Seminar. In the summers of 1982 and 1983 I offered a course in Combinatorics for advanced high school participants.

ADMINISTRATIVE EXPERIENCE AT THE OHIO STATE UNIVERSITY

From October 1980 through December 1985 I was responsible for the scheduling of the Department of Mathematics' student and adjunct teaching staffs of 300 persons. As Program Associate, I was responsible for the hiring, training, evaluation, review and nonacademic renewal of student and adjunct part–time teaching staff, disbursing a budget of $1.7 million. I was responsible for obtaining and maintaining offices and office furnishings for that same staff. I had responsibility for scheduling classrooms for quarterly Mathematics enrollments of up to 17,000 students. I oversaw the Ohio State Mathematics Department’s Evening and Weekend Programs with an annual enrollment of 5000 students. As the departmental liaison with the Office of Continuing Education, I had the responsibility for developing internal funding proposals for new and continuing programs. I acted as a resource to the Mathematics Department Advising Center on issues of transfer and placement especially for graduate and international students. During the period from 1980 through 1988, I acted as the second of two officers of the Department in matters of academic misconduct and sexual harassment.

During my tenure as Program Associate, I accomplished a major reorganization of departmental policies and procedures for handling adjunct staff, offices, salaries, training, and enrollment projections. I developed computer based record keeping systems and procedures for updating and maintaining them. My involvement in scheduling, staffing, and instruction required that I be an active (nonvoting) participant in the Department's Undergraduate, Honors, and Graduate Studies Committees. Additionally, I served on University–wide committees on issues of Registration, Classroom Scheduling, and TA Training. I developed strong contacts in the Office of Disability Services and functioned as departmental liaison with that office. My review of Departmental space needs and resources initiated a process that resulted in the construction of a new Mathematics Building after my departure.

**Bruce William Yoshiwara**
Atascadero, California

## Education

Ph.D., Mathematics (UCLA, 1988), MA, Mathematics (UCLA, '78), BA, Mathematics (UCLA, '76)

## Professional experience

Professor of Mathematics
Los Angeles Pierce College
1989 – 2014

Fulbright Exchange Teacher
Barnsley College (Yorkshire, England)
1998 – 1999

Staff Engineer
Hughes Aircraft/Radar Systems Group
1982 – 1989

Instructor of Mathematics
Los Angeles Harbor College
January – June 1985

Instructor of Mathematics and Physics
Marymount High School
1980 – 1982

Teaching Associate of Mathematics
University of California Los Angeles
1976 – 1979

## Publications

"Life After Wolfram|Alpha: What You (and Your Students) Need to Know," *Loci*, February 2010, (with Gizem Karaali): http://tinyurl.com/yz2r59j
"A Different Pencil Too Good to be Ignored? A First Look at Wolfram|Alpha", MAA Focus, October-November 2009 (with Gizem Karaali)
*Trigonometry*, xyzTextbooks, 2013 (with Katherine Yoshiwara)
*Essential Algebra*, xyzTextbooks, 2013 (with Katherine Yoshiwara)
*Essential Algebra*, Pearson (custom), 2009 (with Katherine Yoshiwara)
*Prealgebra* (2nd), Brooks-Cole, 2003 (with Katherine Yoshiwara)
*Introductory Algebra: Equations and Graphs*, Brooks-Cole, 2004 (with Katherine Yoshiwara)
*Intermediate Algebra*, Brooks-Cole, 2004 (with Katherine Yoshiwara)
*Modeling, Functions, and Graphs* (4th), Brooks-Cole, 2007 (with Katherine Yoshiwara)
*Elementary Algebra*, Brooks-Cole, 2000 (with Katherine Yoshiwara)
"Terminate the Terminator!", MathDL *Loci Resources* (interactive lesson in Flash)

## Professional Activities and Awards

Curriculum Framework and Evaluation Criteria Committee July 2012 – Feb 2013
Carnegie Alpha Lab Research Network Steering Committee August 2012 – Aug 2014
2011 Hayward Award recipient
Carnegie Foundation for the Advancement of Teaching Statway project faculty team member, 2010 – 2012
Keynote speaker, Teaching Mathematics on the Web SIGMAA, Joint Mathematics Meeting, San Francisco January 2010

American Mathematical Association of Two-Year Colleges 2009 *Teaching Excellence Award* recipient
Southern California-Nevada Section of the Mathematical Association of America 2008 *Award for Distinguished College or University Teaching of Mathematics* recipient
Co-PI NSF grant DUE 7428-0410842 *Planning Digital Products To Strengthen Two Year College Mathematics Teaching and Learning*, 2007 – 2009
Panelist reviewing NSF grant proposals, 1995, 2004, 2005, 2007, 2008, 2010, 2012
Keynote speaker, 17th Kansas City Regional Mathematics Technology EXPO, October 2007
California Mathematics Primary Adoption Content Review Panelist, 2006 – 2007
Member of writing team, UCLA's Math Content Program for Teachers, 2003 – 2006
Member of California State University Northridge's Teachers for a New Era subcommittees, 2004 – 2006.
Member of MAA, 1976 – present
Member of NCTM, AMATYC, $CMC^3$ (North and South) 1990 – present
Member of CAMTE, 2006 – present

**Service to Professional Organizations**

Executive board, Southern California/Nevada Section of the MAA, April 2014 – present
Member of MAA focus group to draft a report on Technology and the Undergraduate Mathematics Curriculum, August 2014 – present
Member of AMATYC Association Review Group to comment on the MAA's Curriculum Guide, April – June 2014
California Mathematics Council Community Colleges ($CMC^3$)-South executive board Member, 2006 – 2014
Member of MAA's Committee for Two-Year Colleges, 2010 – 2014
Member of MAA's Curriculum Renewal and the First Two Years (CRAFTY) committee, 2008 – 2014
American Mathematical Association of Two-Year Colleges (AMATYC) West Region Vice-president, 2009 – December 2013
Los Angeles Area Knowledge Exchange network coordinator, 2009 – 2012
Mathematical Association of American (MAA) Mathematical Sciences Digital Library advisory board member, 2008 – August 2013
Editorial board. *Loci* (formerly *Journal of Online Mathematics and its Applications*), 2003 –2013
Consultant, MAA Project NExT (New Experiences in Teaching), 2001 – present
Consulting Colleague for Project ACCCESS (Advancing Community College Career: Education, Scholarship, and Service), 2006 – present (speaker 2007)
Member of AMATYC's Innovative Teaching and Learning Committee, 2008 – present
Member, MathDL New Collection Working Group, June 2010 – 2012
Member and facilitator of AMATYC's Association Review Group to comment on Carnegie Foundation's Statistics Pathway (Statway) project, June 2010
Implementation Coordinator for *Beyond Crossroads*, the standards document (of the American Mathematical Association of Two-Year Colleges), Oct. 2006 – November 2008
Member of AMATYC's Association Review Group to comment on NCTM's *Focus on High School Mathematics*, September 2008
Chair of the MAA Committee on Technologies in Mathematics Education, January 2004 – January 2007 (committee member 2001 – 2007)
Reviewer, California Mathematics Project STIR proposals, January 2007

Member of AMATYC TiME and Distance Learning committees, November 2004 – 2007
Member of review/editorial team for AMATYC's (via President Kathy Mowers) letter to the National Mathematics Advisory Panel, August 2006
Member of review/editorial panel for AMATYC's *Beyond Crossroads Executive Summary*, 2006
Member of search committee for editor of the *Mathematics Magazine*, February – June 2004

**Conferences and Workshops**

Summer Engineering Teaching Institute presenter, June 10, 2013 and June 18 – 19, 2012
MathDL workshop leader, California State University Northridge, May 10, 2013
MathFest Intermediate Algebra session panelist, August 2012
NISOD Student Success Leadership conference speaker, Austin, May 29, 2012
Colloquium speaker, CSU San Bernardino, May 2, 2012
ICTCM proposal review panel chair, 2007–2013 (panelist 2006, speaker 2008, 2011, 2012)
Speaker, $CMC^3$ -South annual spring meetings, Anaheim/Costa Mesa, 1994, 1997, 1998, 2000, 2004, 2006, 2007, 2008, 2009, 2012, 2014
Organizing team member, 3CSN Math conference, Pierce College, April 27, 2012
Program director, LACCD March 11, 2011 Math Summit, LA Trade Tech
Speaker, AMATYC webinar, online, 2011
Facilitator at LACCD NSF Grant Seeking Workshop, February 26, 2010
Speaker, $CMC^3$, Monterey, 1992, 1995, 2000, 2004, 2009, 2010
Speaker, PIMATYC, Honolulu, 2010
Speaker, AMATYC annual meeting, 2000, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2012
Speaker, MAA Southern California-Nevada fall section meeting, October 2009
Invited participant, MAA Mathematics Digital Library Workshop, October 2008
Speaker, 2009 Curtis Center Mathematics and Teaching Conference, February 2009
Luncheon speaker, MAA Southern California-Nevada fall section meeting, October 2008
Speaker, $CMC^3$-South Fall mini-conference, Santa Monica College, September 2008
Co-organizer of "Using New Technologies" invited paper session for January 2008 Joint Mathematics Meeting (San Diego)
Themed session organizer, AMATYC 2007 Annual Meeting (Minneapolis)
Invited workshop participant, Better Practices for Math on Web, July 15-21, 2007
Workshop leader, MathDL/Math Gateway, March 2007
Co-organizer of "Electronic Student Assessment Systems" panel session for January 2007 Joint Mathematics Meeting (New Orleans)
Speaker, California Association of Mathematics Teacher Educators membership meeting Dec 2006
Co-organizer of "Electronic Homework Systems" panel session at January 2006 Joint Mathematics Meeting (San Antonio)
Invited participant, MAA Digital Library Workshop, October 6 – 8, 2006
PMET (Preparing Mathematicians to Educate Teachers) workshop participant, Oswego, NY, June 2005
Organizer for CRAFTY/AMATYC Curriculum Foundation workshop, October 2000
Program Director, $CMC^3$-South Fall mini-conference, September 2000
Speaker, joint meeting of the Association of Teachers of Mathematics and the Mathematics Association, (Liverpool, **England**) April 1999
Speaker, California Mathematics Council, Palm Springs, 1999; Asilomar 2006
Organizer, Mathematics Preparation of Students Conference at UCLA, January 1997

Site Director, Teacher Enhancement Project, 1993 – 1996
Invited participant, ATLAST Advanced Developers' workshop, San Diego, August 1994 and Seattle, August 1996
Speaker, Conference on the Teaching of Mathematics, Baltimore, 1996
Co-PI, NSF Grant DUE-9451326 *Precalculus Lessons Using Technology*, 1994 – 1995
Site Director, Interactive Mathematics Text Project, 1993 – 1995

**Service to Los Angeles Pierce College**
Los Angeles Pierce College Mathematics Department Chair, 1994 – 1997, 2010 – 2012
MAA liaison, 1994 – 1998, 2001 – 2014
Los Angeles Pierce College Mathematics Department Vice-Chair, 2007 – 2010
AMATYC Student League advisor, 1990 – 1994, 2004 – 2008
Developer of associate's degree in mathematics at Pierce College, 2007 – 2008
Faculty mentor, 2007 – 2008
Organizer of Pierce College math department seminar, spring 2003
Math Department webmaster, 1999 – 2003
Editor of department newsletter, 1991–2003
LA Community College District Mathematics Council: Chair 1995 – 1997, member 2012 – 2014

## Other
Speaker, Santa Ana College, 2014
Speaker, Valencia Community College (Florida), 2005
Guest lecturer at MCPT courses (Math and Technology, Advanced Geometry) 2004–2005
Speaker, Chemeketa Community College (Oregon), 2004
Contributor of two of the *College Math Journal's* "Fallacies, Flaws, and Flimflam" Fulbright Exchange Teacher (to Barnsley College, England), 1998 – 1999
Barnsley College liaison with Academic Systems, 1998 – 1999
Speaker, Barnsley College Mathematics department, March 1999
Speaker, Kalamazoo Valley Community College, August 1997
Speaker, Irvine Valley College, September 1996
Speaker, Conference on the Teaching of Mathematics, 1994 and 1996
Speaker, University of Arizona, Tucson, January 1996
Speaker, Santa Monica College Math Department, May 1993
Speaker, LACCD Math Council Workshops, October and November 1993
Reviewer of numerous mathematics textbooks and software

**NB**: Bruce Yoshiwara is the only community college faculty member to serve on the Curriculum Framework and Evaluation Criteria Committee or ever to serve as "math expert" in California's state textbook adoption process. He is the only community college faculty member to chair the MAA's technology committee. He is the only community college member to serve on the editorial board of Loci. He is one of only two (Kathy Yoshiwara is the other) persons ever to be honored with both the Southern California Section of the MAA Distinguished Teaching Award and the AMATYC Teaching Excellence Award. His "Folding Conics" presentation was used as source material for Museo Tridentino di Scienze Naturali–Trento, Italy book for teachers, and for a GeoGebra applet in the GeoGebra wiki. The presentation "Bicycles, Birds, Bats, and Balloons: New Applications for Algebra Classes"—co-presented with Katherine Yoshiwara—is in ERIC, the Educational Resources Information Center. He has written for newsletters of AMATYC, $CMC^3$, $CMC^3$ -South, CAMTE, NADE Math SPIN, and the Southern California-Nevada MAA Section. He was quoted in the June 17, 2009 issue of the *Wall Street Journal* regarding the possible impact of Wolfram|Alpha.

**Terran Felter**
Bakersfield, California

EDUCATION
2000 - 2002 University of California, Riverside - Riverside, CA
Master of Science, Mathematics

1997 - 2000 California State University, Bakersfield - Bakersfield, CA
Bachelor of Science, Applied Mathematics

EXPERIENCE
2007 - 2012 University of La Verne - Bakersfield, CA
*Kern County Regional Campus*
Part-time faculty member, teaching College Algebra and Instructional Approaches to Mathematics on an as-needed basis.

2002 - present California State University, Bakersfield - Bakersfield, CA
*Developmental Mathematics Program*
Fall 2009 – present:: Coordinator and sole instructor for developmental mathematics classes, responsible for recruiting, hiring, and scheduling Instructional Student Assistants to staff the developmental mathematics classes; along with the chair of mathematics, recruiting and hiring instructors for General Studies support courses for developmental mathematics classes; hiring, coordinating, and supervising instructors and Instructional Student Assistants for summer programs; and work closely with the campus remediation advisor to track progress of incoming freshman requiring mathematics remediation.

*Department of Mathematics*
Fall 2009 - Summer 2009: Lecturer, responsible for all aspects of the instruction of the equivalent of eight courses per year which include developmental mathematics, mathematics education, pre-calculus, and calculus. Coordinator of CSUB's Developmental Mathematics Program, responsible for chairing Developmental Mathematics meetings; curriculum and textbook issues; and hiring and supervising Instructional Student Assistants for the ALEKS classes. Coordinator of *America Counts*, a federally funded program which places undergraduate tutors in local middle schools.

2000 – 2005 California State University, Bakersfield - Bakersfield, CA
*Academic Advancement Center and College Assistance Migrant Program*
Instructor, Summer Bridge and CAMP, responsible for teaching intermediate algebra to incoming college freshmen in a four week summer program designed to acclimate students to college life.

2000 – 2002 University of California, Riverside - Riverside, CA
*Department of Mathematics*
Teaching Assistant, responsible for assisting in all aspects of the instruction of first and second quarter calculus, applied matrix algebra, and ordinary differential equations.

1998 – 2000 California State University, Bakersfield - Bakersfield, CA
*Department of Mathematics*
Tutor, responsible for assisting students in algebra, geometry, trigonometry, pre-calculus, first quarter calculus, business calculus, statistics, and mathematics for elementary school teachers in the Math Tutoring Center.

Andrew Hicks
Bakersfield, CA 93314

**PROFESSIONAL EXPERIENCE**

2013 – present: Stockdale High School, Bakersfield, CA
Mathematics Teacher

2011 – 2013: Kern High School District Instructional Services, Bakersfield, CA
Resource Teacher for Mathematics

1999 – 2011: Liberty High School, Bakersfield, CA
Resource Teacher for Technology

1998 – 1999: Kern High School District
Resource Teacher for Technology

1992 – 1998: Stockdale High School, Bakersfield, CA
Mathematics Teacher

1992 – 1994: California State University, Bakersfield
Adjunct Lecturer for Mathematics

1990 – 1992: Highland High School, Bakersfield, CA

1989 – 1990: Actis Junior High School, Bakersfield, CA

1986 – 1989: Torrance High School, Torrance, CA
High School Basketball Coach

1983 – 2010: Varsity and Junior Varsity coach at the high schools listed above

2010: Kern County Coach of the Year – C.I.F. Division 2 Valley Champions

2009: Kern County Coach of the Year – C.I.F. Division 2 Valley Runner-up,
SEYL League Champions

**EDUCATION**

2002: University of La Verne
Master of Education (M.Ed.) in Educational Management
Thesis: “Integrating Technology into Mathematics Instruction”

1988: California State University, Dominguez Hills
Single Subject Teaching Credential in Mathematics

1986: University of California, Los Angeles
Bachelor of Science (B.S.) in Electrical Engineering

**PROFESSIONAL ACTIVITIES AND AWARDS**

2013 – present
*Mathematics Teacher*. After two years of providing staff development for teachers on Common Core mathematics implementation, I chose to go back to the classroom. It has been a joy to return to the trenches and have the opportunity to implement the new CCSS standards, which is a return to how mathematics should be presented to students.

2011 – 2013
*Kern High School District Resource Teacher for Mathematics*. Was asked by the Assistant Superintendent of Instruction to serve as the district's mathematics curriculum leader. Provided in-service and guidance to the district's new teachers. Facilitated monthly meetings of our 20 math department chairs. In spring 2011, the major work of this position was to begin implementation of the CCSS. That spring, we began with Awareness sessions, followed by our "Ramp Up the Rigor" series the next fall. These past several years, the focus is now on upgrading the mathematics content.

1999 – 2011
*Mathematics Department Chair*. Led our departmental team which built Liberty's mathematics curriculum from the ground up, including new KHSD standards-based courses such as Statistics P, Applied Geometry, and Integrated Math. Yearly organized the math master schedule and subject area groups (now PLC teams). Led departmental meetings and mentored new Liberty math teachers. Attended department chair meetings both at LHS and the district office.

2004-05 and 2010-11
*WASC Curriculum and Instruction Committee Co-Chair*. Co-chaired committees of Liberty faculty for our first two WASC visitations. 2004-05: Curriculum and Instruction Committee. 2010-11: Instruction Committee.

1983 – 2010
*High School Basketball Coach.* Began coaching at my high school alma mater, Torrance High School, while attending UCLA. Over the many years, coached Varsity and Junior Varsity teams. As Varsity coach, served as general manager for

all three levels of teams, led parent meetings, chaired booster club meetings, and organized fundraising efforts.

2008-09 and 2009-10
*Kern County Basketball Coach of the Year*. Elected by coaching peers, for two consecutive seasons.

2010-11
*PLC Leader Advanced Algebra*. Led PLC curriculum meetings, organized shared assessments and other materials for Advanced Algebra.

July 2010 and July 2011
*PLC Hollywood Conference*. Attended the PLC Conference the past two summers, receiving valuable ideas on how to implement the PLC process at our school site. In August of 2010, was among a group of five Liberty teachers that led PLC staff development in our start-of-school meetings for all teachers.

2010-11
*PLC Mathematics Training*. Received math-specific training on implementing common formative assessments and analysis of student data. Marzano's "The Art and Science of Teaching"

Teacher Leadership Training, 2010-11
Was selected by the Liberty administration to be part of the first cohort to receive this training. We then went back to our site and shared key ideas with both a "learning-buddy" and all teachers in our departments.

2007-08
*KHSD Common Mathematics Textbook Committee Member*. Reviewed and selected textbooks for Geometry and Advanced Algebra for district-wide use.

2005-06 and 2006-07
*KHSD Geometry Benchmark Committee Chairman*. Chaired the committee of KHSD Geometry teachers selected to develop a district-wide curricular blueprint. This was initially a challenge as so many different Geometry books were being used in the KHSD. Eventually a consensus was reached for the blueprint. The district benchmark exams were written and revised over the two school years.

2005-06 and 2006-07
*KHSD Algebra 1 Benchmark Committee Member*. Also served on the Algebra 1 committee which wrote the district Algebra 1 blueprint and benchmark exams.

2003-04 and 2004-05
*Professional Development Leader (PDL), Liberty High School*. Served as teacher leader for Liberty High School staff development on power standards, unwrapping the standards, essential concepts and skills, common rubrics for assessment, and performance assessments.

2003-04
*KHSD Math Alignment Project (MAP) Committee Member*. Served on the committee which was charged to clean up the many different ways pre-algebra and algebra were being taught in the KHSD. The group finalized the courses of study for Foundations 1, Foundations 2, and Algebra 1P.

1999-2001
*Liberty's Digital High School Grant, Principal Writer*. Chaired Liberty's Technology Committee and authored the 30-page grant for nearly $500,000 worth of technology and staff development funds.

1999-2000
*Teacher of the Year*. Liberty High School (LHS's inaugural year). Stockdale High School 1996-97.

1998-99
*KHSD Resource Teacher for Technology*. Served as teacher leader and program coordinator for the new KHSD Starrh Computer Lab. Organized and led workshops for district staff on basic uses of computers, applications of educational technology, and project based learning. Led staff development workshops at individual schools as requested by site administration. Mentored teachers new to computers.

1998-99
*Stockdale's Digital High School Grant, Co-Writer*. Collaborated with the Stockdale faculty, technology committee, and DHS grant team. Co-authored the DHS grant with Assistant Principal Ramon Hendrix and Librarian Mary Lee.

1997-98
*KCSOS CTAP Technology Mentor*. Led educational technology workshops for teachers of Kern County with an emphasis on "Project Based Learning."
*High School Web Master*. Created and maintained both Stockdale and Liberty's original web sites until they were taken over by student classes.

1996-97 and 1997-98
*KHSD Mentor Teacher*. Mentored new teachers at Stockdale High. Also led district-wide workshops for new uses of educational technology.

1992-94
*Adjunct Lecturer for Mathematics, California State University, Bakersfield*. Taught Math 320 (Algebra 1) and Math 321 (Geometry) classes to future elementary teachers. Also taught Math 90, an Algebra II course for college students in need of remediation.

**KYLE ATKIN**
Bakersfield, California

EDUCATION

California State University, Bakersfield, CA
**M.A. in Teaching Mathematics** **2009**

California State University, Bakersfield, CA
**B.S. Mathematics** **2000**

AWARDS

Outstanding Graduating Graduate - Mathematics **2009**

TEACHING EXPERIENCE

Kern High School District
**Mathematics Resource Teacher** **2013-Present**

Create and deliver professional development; implement transition to Common Core State Standards

**Teacher – Arvin High School** **2000-2013**

Taught mostly Algebra and Advanced Placement Statistics

RELATED EXPERIENCE

Teachers Teaching with Technology – Texas Instruments
**Regional Instructor** **2005 – Present**

Provide professional development related to the implementation of graphing calculator technology

MEMBERSHIPS

National Council of Teachers of Mathematics
California Mathematics Council
Bakersfield Mathematics Council

**Brian J. Shay**
San Diego, California

**EDUCATION**

June 2002 — **Masters of Arts in Teaching**, University of California at Davis
Joint program with Department of Mathematics and School of Education. Emphasis on integration of technology (handheld and desktop) into a discovery, and standards-based classroom environment.

January 2002 — **California Single Subject Teacher Credential in Secondary Mathematics**, UC Davis
Focused on integration of technology into high school curriculum, teaching using constructivist ideals, standards-based instruction and assessment. CLAD certified.

December 2000 — **Masters of Arts in Mathematics**, University of California at Davis,
Pure mathematics master's program, emphasis on topology, minimal surfaces, geometry.

May 1998 — **Masters of Arts in Mathematics**, State University of New York College at Potsdam,
Pure mathematics program, emphasis on topology, minimal surfaces, geometry.

May 1998 — **Bachelors of Arts** State University of New York College at Potsdam
Major: Mathematics (B.A./M.A. Program), *Summa cum laude*: 3.92
Minor: Acting, Emphasis: Directing, Concentration at the Crane School of Music: Voice

**PUBLICATIONS**

The Shortest Enclosure of Two Connected Regions in a Corner, Hruska, Shay, etc. Rocky Mountain Journal of Mathematics, Volume 31, Number 1, 2001.

**EXPERIENCE**

**Curriculum Coordinator and Teacher on Special Assignment** — San Dieguito Union High School District, Encinitas, California

January 2005 – January 2009, June 2013 - Present — Lead monthly meetings with the chairs from all the schools in the district with the goal of building consistency for all students in the district. Created and lead monthly professional development for all math teachers focused on Common Core State Standards, mapping standards, creating scope and sequence, task development, assessments, and evaluating instructional materials. Wrote district level standards based formative assessments. Created and lead parent information nights to educate our community about the CCSS-M.

**Teacher and Chair** — Canyon Crest Academy High School, San Dieguito Union High

| | |
|---|---|
| | School District |
| August 2004 – Present<br>Chair: August 2004 – January 2009, June 2013 - Present | Teach Algebra I, Geometry, Honors Geometry, Honors Algebra II, Honors Pre Calculus<br>AP Calculus AB/BC, AP Statistics, Calculus III and Linear Algebra. Team-taught Algebra I for Special Education students with a Special Education teacher. Coach the math team to numerous victories at the county, state and national levels. Integrate use of graphing calculators, Geometer's Sketchpad, Mathematica and Tablet PCs into curriculum on a daily basis. Align all courses to California Common Core state standards and AP standards. As Chair: interview, hire and evaluate teachers. Support new hires with curricular and classroom needs by making regular observations and offering academic support. |
| **Adjunct Instructor**<br>August 2013 – Present | University of California, San Diego, College of Extended Studies<br>Teach Calculus III (Math 20C) and Linear Algebra (Math 20F). Used MATLAB to teach linear algebra. Coordinated instructors as program grew. |
| **Mentor Fellow**<br>August 2011 – Present | Math for America, San Diego<br>Mentor Teaching Fellows in their first five years of teaching with their content knowledge, classroom management, bringing research into practice, and job placement. Support and mentor Master Teaching Fellows as they become leaders and reflective teachers. Run a three week summer institute, and four follow-up Saturday sessions, focused on deepening teacher mathematical knowledge in relation to the CCSS-M. Created and conducted professional development for San Diego county educators learning more about the CCSS-M, instructional materials and the DNR Theoretical Framework. Created and taught Summer Enrichment Academy for local middle and high school math students where the content was focused on developing proportional reasoning and the Standards for Mathematical Practice and the CCSS-M. |
| **Chairperson** | California Teacher Advisory Council, California Council on Science and Technology |
| January 2010 – February 2014 | Advised the California Congress members, State Legislatures, Department of Education, University and College administrators and faculty, and private company leaders on the needs of STEM education. Coordinated and conducted symposia and colloquia which brought together leaders from public, private and philanthropic communities to discuss STEM education, assessment, digitally enhanced education, and teacher training. Published reports and white papers advising policy makers on STEM education. |
| **Adjunct Instructor** | Mesa College, San Diego Community College District |
| August 2003 – Present | Teach Pre-Algebra, Elementary Algebra, Intermediate Algebra, |

College Algebra,
Trigonometry, Statistics (online and traditional), Calculus I and II, and online "Refresher" classes. Evaluated and adopted textbooks for Pre-Algebra, Statistics, and Trigonometry.

**HONORS AND AWARDS**

2014 MIT Inspirational Teacher
2013 Summa Education STEM Teacher of the Year
2012 George Polya Memorial Award, California Mathematics Council
2012 California Mathematics Curriculum Framework and Evaluation Criteria Committee Member
2011 *Mathematics Framework for California Public Schools* Focus Group member
2010 California Academic Content Standards Commissioner
2009 San Dieguito Union High School District Teacher of the Year and Canyon Crest Academy Teacher of the Year.
2009 Crystal Apple Award from the Church of Latter Day Saints
2009 Greater San Diego Math Council's Outstanding High School Math Teacher.
2009 *Mathematics Framework for California Public Schools* Focus Group member
2008 Fulbright-Hays Scholar in India learning about schools, culture and curricula.
2004 Joseph B. Whitehead Educator of Distinction Award.
First person in the history of SUNY Potsdam to graduate with a BA and MA in 3 years.
Phi Kappa Phi Honor Society, SUNY Potsdam.
Pi Mu Epsilon Math Honor Society, SUNY Potsdam.
SUNY Potsdam Presidential Scholar.

**PROFESSIONAL DEVELOPMENT AND CONFERENCE PRESENTATIONS**

SAT Math Subject Test Development Committee Member, 2014 – 2015
Panelist: Demystifying the Common Core Standards for Mathematics with Phil Daro
Panelist: 21st Century Learning Skills for a Path to Success
MIT Science and Engineering Program for Teachers, 2014
National Council of Teachers of Mathematics, Annual Meeting: 2014
Mathematics Diagnostic and Testing Project, 2014 Annual Meeting: Plenary Speaker
Advanced Placement Calculus Exam Reader, 2014 – 2010,
Park City Math Institute, Secondary School Teachers Program, 2013
Program Chair, California Mathematics Council – South Meeting, 2014 - 2010.
CCSS-Math Consultant for Irvine Unified School District 2011 – 2013.
California Math Council – North Meeting: 2013
California Math Council – South Meeting: 2005 – 2013.
Curtis Center for Teaching and Learning Annual Conference: 2010 - 2013.
Greater San Diego Mathematics Council Annual Conference: 2011,

2010.
Orange County Math Conference: 2008, 207.
Los Angeles County Teachers of Mathematics, Annual Meeting 2008.
National Council of Teachers of Mathematics, Annual Meeting 2008.
Member of NCTM, NCSM, MAA, NEA, AFT, CMC and GSDMC.

**ADDITIONAL TEACHING EXPERIENCE**

**Teacher**
August 2002 – June 2004

La Costa Canyon High School, San Dieguito Union High School District
Teach Algebra 1, Pre-Calculus, Honors Pre-Calculus, and AP Calculus AB and BC.
Coached Mu Alpha Theta, the math team, to many county-wide victories. Member of subject-level committees to build consistent curriculum and assessment.

**Teacher**
June 2001 – August 2002

River City High School, Washington Unified School District
Taught Geometry, Algebra, and Pre-Algebra. Integrated Geometer's Sketchpad into
Geometry class weekly. Served as an unofficial technology consultant for faculty.
Attended professional development meetings at the Sacramento County office of Education on writing benchmark exams and backwards mapping of the standards.

**Associate Instructor**
September 1999 – August 2001

Mathematics Department, U.C. Davis
Taught two sections of Calculus III for Math/Science majors. Taught, held office hours and assessed students' understanding. Supervised an undergraduate homework grader.

**Teacher's Assistant**
March 1999 – June 2001

Mathematics Department, U.C. Davis
Assisted professor with all grading. Led weekly discussion sections where students asked questions and professor requested presentation of specific topics. Substituted. Held office hours. Classes included Pre Calculus, Calculus I, II and III, Linear Algebra, Computer Lab Assistant, Introduction to Abstract Mathematics, and Euclidian Geometry.

# APPENDIX C: DEPTH-OF-KNOWLEDGE LEVELS BY ITEM AND REVIEWERS; INTRACLASS CORRELATION

| Item | Rater 1 | Rater 2 | Rater 3 | Rater 5 | Rater 6 | Rater 7 |
|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 2 | 1 | 2 | 2 |
| 2 | 1 | 2 | 1 | 3 | 1 | 1 |
| 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | | | | | | |
| 5 | 1 | 2 | 1 | 2 | 1 | 2 |
| 6 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7 | 2 | 2 | 2 | 2 | 2 | 2 |
| 8 | 1 | 2 | 1 | 2 | 2 | 2 |
| 9 | 2 | 2 | 2 | 2 | 2 | 1 |
| 10 | 2 | 1 | 1 | 1 | 1 | 1 |
| 11 | 2 | 2 | 1 | 1 | 2 | 2 |
| 12 | 2 | 1 | 1 | 2 | 2 | 2 |
| 13 | 2 | 2 | 1 | 1 | 2 | 1 |
| 14 | | | | | | |
| 15 | 1 | 1 | 1 | 1 | 2 | 1 |
| 16 | 1 | 1 | 1 | 2 | 1 | 1 |
| 17 | 2 | 2 | 1 | 2 | 2 | 2 |
| 18 | 2 | 1 | 2 | 2 | 1 | 2 |
| 19 | 1 | 2 | 2 | 1 | 1 | 2 |
| 20 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21 | 2 | 2 | 2 | 2 | 2 | 2 |
| 22 | 1 | 2 | 1 | 1 | 2 | 1 |
| 23 | 2 | 2 | 2 | 1 | 2 | 2 |
| 24 | | | | | | |
| 25 | 1 | 1 | 2 | 1 | 2 | 2 |
| 26 | 2 | 2 | 2 | 2 | 2 | 2 |
| 27 | 1 | 2 | 2 | 1 | 2 | 2 |
| 28 | 1 | 1 | 2 | 1 | 1 | 2 |
| 29 | 1 | 2 | 1 | 1 | 3 | 3 |
| 30 | 2 | 2 | 3 | 1 | 3 | 3 |
| 31 | 2 | 2 | 2 | 1 | 3 | 3 |
| 32 | 2 | 2 | 1 | 1 | 2 | 3 |
| 33 | 1 | 3 | 3 | 2 | 3 | 3 |
| 34 | | | | | | |
| 35 | 3 | 3 | 2 | 1 | 2 | 3 |
| 36 | 2 | 3 | 2 | 2 | 3 | 2 |
| 37 | 3 | 3 | 2 | 1 | 2 | 2 |

| Item | Rater 1 | Rater 2 | Rater 3 | Rater 5 | Rater 6 | Rater 7 |
|---|---|---|---|---|---|---|
| 38 | 1 | 1 | 1 | 2 | 1 | 2 |
| 39 | 3 | 2 | 2 | 1 | 2 | 3 |
| 40 | 1 | 1 | 1 | 1 | 1 | 2 |
| 41 | 3 | 2 | 2 | 2 | 2 | 3 |
| 42 | 3 | 4 | 2 | 2 | 2 | 3 |
| 43 | 1 | 1 | 2 | 2 | 2 | 3 |
| 44 | | | | | | |
| 45 | 3 | 4 | 2 | 1 | 2 | 3 |
| 46 | 2 | 2 | 2 | 2 | 2 | 3 |
| 47 | 2 | 1 | 2 | 1 | 2 | 3 |
| 48 | 2 | 3 | 2 | 1 | 2 | 3 |
| 49 | 3 | 3 | 2 | 3 | 2 | 2 |
| 50 | 2 | 3 | 2 | 1 | 3 | 3 |
| Intraclass Correlation Higher Mathematics (9-12) | | | | | 0.754 | |

(Note:  There is no Rater 4. The entry was a duplicate reviewer registration. No entries were made for Rater 4. The WAT excludes incomplete entries from alignment calculations.)

# APPENDIX D: DOK LEVELS AND OBJECTIVES CODED BY EACH REVIEWER; PAIRWISE AGREEMENT

| Item | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | S2 Obj | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | DOK | P Obj |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2.1b | 2.2a | 2 | | | 2 | | | | 1 | | | 2 | | | 2 | 5.1a |
| 2 | 1 | 2.1b | | 2 | 2.5a | | 1 | 2.9a | 2.9b | | 3 | 2.2a | | 1 | 2.2a | | 1 | 2.1d |
| 3 | 1 | | | 1 | | | 1 | | | | 1 | | | 1 | | | 1 | 1.2a |
| 4 | | | | | | | | | | | | | | | | | | |
| 5 | 1 | 2.9b | | 2 | | | 1 | | | | 2 | | | 1 | | | 2 | 2.3a |
| 6 | 1 | 5.1b | | 1 | | | 1 | | | | 1 | | | 1 | 5.1 | | 1 | 1 |
| 7 | 2 | 4.6b | | 2 | | | 2 | 4.3b | | | 2 | 1.3a | | 2 | 4.6b | | 2 | 4.3c |
| 8 | 1 | 3.3b | | 2 | 4.11b | | 1 | 3.3b | 3.5a | | 2 | 2.11a | 2.11c | 2 | 3.5a | | 2 | 3.5a |
| 9 | 2 | 4.1a | | 2 | | | 2 | 4.3a | | | 2 | 1.3a | | 2 | | | 1 | 4.3a |
| 10 | 2 | | | 1 | | | 1 | | | | 1 | | | 1 | | | 1 | 1 |
| 11 | 2 | 1.3a | | 2 | | | 1 | 1.3a | | | 1 | | | 2 | 1.3a | | 2 | 2.8a |
| 12 | 2 | | | 1 | | | 1 | 4.13a | | | 2 | 1.3a | | 2 | | | 2 | 4.9b |
| 13 | 2 | 1.3a | | 2 | | | 1 | 1.3a | | | 1 | | | 2 | | | 1 | 1 |
| 14 | | | | | | | | | | | | | | | | | | |
| 15 | 1 | | | 1 | | | 1 | | | | 1 | | | 2 | 5.2a | | 1 | 1 |
| 16 | 1 | 2.1b | 2.2e | 1 | 2.3a | | 1 | 2.3a | | | 2 | 2.3a | | 1 | 2.3a | | 1 | 2.2a |
| 17 | 2 | | | 2 | | | 1 | 4.3a | | | 2 | 1.3a | | 2 | | | 2 | 4.3a |
| 18 | 2 | 2.2a | 2.1d | 1 | 2.6a | | 2 | 2.1d | 2.6a | | 2 | 2.2a | | 1 | 2.3a | | 2 | 2.6a |
| 19 | 1 | 1.1a | | 2 | 2.3a | | 2 | 2.8b | | | 1 | 2.8b | 1.2a | 1 | 1.1b | | 2 | 2.9a |
| 20 | 1 | | | 1 | | | 1 | | | | 1 | | | 1 | 1.1b | | 1 | 1.1 |
| 21 | 2 | | | 2 | | | 2 | 4.3c | | | 2 | 1.3a | | 2 | | | 2 | 4.7c |
| 22 | 1 | | | 2 | | | 1 | | | | 1 | | | 2 | | | 1 | 1.2 |
| 23 | 2 | | | 2 | | | 2 | 3.4a | | | 1 | | | 2 | | | 2 | 2.7a |
| 24 | | | | | | | | | | | | | | | | | | |
| 25 | 1 | 1.1a | 2.1a | 1 | 3.1b | | 2 | 3.1b | 2.8b | | 1 | 2.8b | | 2 | 1.1b | | 2 | 3.1b |
| 26 | 2 | 3.1b | | 2 | 3.1b | | 2 | 3.1b | | | 2 | 2.11a | | 2 | 3.1b | | 2 | 3.1b |
| 27 | 1 | 2.9a | | 2 | 2.9a | | 2 | 2.2a | | | 1 | 2.8b | | 2 | 2.7d | | 2 | 2.7d |
| 28 | 1 | 2.6b | | 1 | 2.6a | | 2 | 2.6b | | | 1 | | | 1 | 2.2a | | 2 | 2.2a |
| 29 | 1 | 5.1a | 5.1b | 2 | | | 1 | 5.1a | 5.1b | | 1 | | | 3 | 5.1c | | 3 | 5.1a |
| 30 | 2 | 1.3a | 5.1a | 2 | | | 3 | 2.7b | 2.9a | | 1 | | | 3 | | | 3 | 5.2b |
| 31 | 2 | 5.4a | | 2 | | | 2 | 5.5b | | | 1 | | | 3 | 5.5b | 5.5a | 3 | 5.1 |
| 32 | 2 | | | 2 | | | 1 | | | | 1 | | | 2 | | | 3 | 4.12d |
| 33 | 1 | 5.1a | | 3 | 2.7a | 2.9a | 3 | | | | 2 | 1.3a | | 3 | 5.1b | | 3 | 5.1b |
| 34 | | | | | | | | | | | | | | | | | | |
| 35 | 3 | 3.1a | 3.1b | 3 | 3.1a | | 2 | | | | 1 | | | 2 | 3.1b | | 3 | 3.1b |

| Item | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | S2 Obj | DOK | PObj | S1 Obj | DOK | PObj | S1 Obj | DOK | P Obj |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 2 | 3.3a | 1.3a | 3 | 3.4b | | 2 | 2.7a | | | 2 | 2.7a | | 3 | 1.3a | | 2 | 2.2a |
| 37 | 3 | 1.3a | 2.9a | 3 | | | 2 | 2.7a | 2.9a | | 1 | | | 2 | 2.7a | | 2 | 2.7a |
| 38 | 1 | | | 1 | 2.9b | | 1 | 2.9b | | | 2 | 2.9b | | 1 | 2.9b | | 2 | 2.7a |
| 39 | 3 | 4.3b | | 2 | | | 2 | 4.3b | | | 1 | | | 2 | | | 3 | 4.3a |
| 40 | 1 | | | 1 | | | 1 | 1.1a | 1.1b | | 1 | | | 1 | | | 2 | 1.1b |
| 41 | 3 | 3.4a | 3.4b | 2 | 3.4b | | 2 | 2.7a | | | 2 | 2.7a | | 2 | 2.7a | | 3 | 2.2a |
| 42 | 3 | | | 4 | | | 2 | 3.3b | 4.6a | | 2 | 4.12b | | 2 | 4.12d | | 3 | 4.12d |
| 43 | 1 | 3.1b | | 1 | 3.4d | | 2 | 3.1b | 3.4d | 2.3a | 2 | 3.1b | | 2 | 3.1b | | 3 | 3.1b |
| 44 | | | | | | | | | | | | | | | | | | |
| 45 | 3 | 4.6a | | 4 | | | 2 | 2.7a | 2.9a | | 1 | | | 2 | 4.7d | | 3 | 4.3b |
| 46 | 2 | 5.3a | | 2 | 5.3a | | 2 | 3.3b | 3.2a | 1.3a | 2 | 1.3a | | 2 | 3.6c | | 3 | 2.11a |
| 47 | 2 | 5.1a | | 1 | | | 2 | 5.1a | 5.1b | | 1 | | | 2 | | | 3 | 5.1a |
| 48 | 2 | | | 3 | | | 2 | 4.13a | | | 1 | | | 2 | 4.10 | | 3 | 4.10 |
| 49 | 3 | 1.3b | 1.3a | 3 | 2.10b | | 2 | 2.10b | | | 3 | 4.10a | | 2 | 2.10b | | 2 | 2.10b |
| 50 | 2 | 1.3a | | 3 | 2.10b | 3.4b | 2 | 2.10b | | | 1 | | | 3 | 3.6b | | 3 | 2.10b |
| Objective Pairwise Comparison: 0.2205<br>Standard Pairwise Comparison: 0.5995 | | | | | | | | | | | | | | | | | | |

DOK: Depth-of-Knowledge
POBJ: Primary Objective
S1Obj: Secondary Objective 1
S2Obj: Secondary Objective 2

# APPENDIX E: GROUP CONSENSUS ON DOK LEVELS OF OBJECTIVES

| Level | Description | DOK |
|---|---|---|
| 1 | Number and Quantity | 1 |
| 1.1 | Extend the properties of exponents to rational exponents. | 2 |
| 1.1a | 1. Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents. For example, we define 51/3 to be the cube root of 5 because we want (51/3)3 = 5(1/3)3 must equal 5. | 2 |
| 1.1b | 2. Rewrite expressions involving radicals and rational exponents using the properties of exponents. | 1 |
| 1.2 | Use properties of rational and irrational numbers. | 2 |
| 1.2a | 3. Explain why the sum or product of two rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational. | 2 |
| 1.3 | Reason quantitatively and use units to solve problems. | 2 |
| 1.3a | 1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.* | 2 |
| 1.3b | 2. Define appropriate quantities for the purpose of descriptive modeling.* | 3 |
| 1.3c | 3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.* | 2 |
| 1.4 | Perform arithmetic operations with complex numbers. | 1 |
| 1.4a | 1. Know there is a complex number i such that i2= -1, and every complex number has the form a + bi with a and b real. | 1 |
| 1.4b | 2. Use the relation i2= -1 and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers. | 1 |
| 1.4c | 3. (+) Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers. | 1 |
| 1.5 | Represent complex numbers and their operations on the complex plane. | 2 |
| 1.5a | 4. (+) Represent complex numbers on the complex plane in regular and polar form (including real and imaginary numbers), and explain why the rectangular and polar forms of a given complex number represent the same number. | 2 |
| 1.5b | 5. (+) Represent addition, subtraction, multiplication, and conjugation of complex numbers | 2 |

| Level | Description | DOK |
|---|---|---|
| | geometrically on the complex plane; use properties of this representation for computation. For example, (-1 + v3 i) 3 = 8 because (-1 + v3 i) has modulus 2 and argument 120°. | |
| 1.5c | 6. (+) Calculate the distance between numbers in the complex plane as the modulus of the difference, and the midpoint of a segment as the average of the numbers and its endpoints. | 1 |
| 1.6 | Use complex numbers in polynomial identities and equations. | 1 |
| 1.6a | 7. Solve the quadratic equations with real coefficients that have complex solutions. | 1 |
| 1.6b | 8. (+) Extend polynomial identities to the complex numbers. For example, rewrite x2 + 4 as (x +2i)(x-2i). | 1 |
| 1.6c | 9. (+) Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials. | 1 |
| 1.7 | Represent and model with vector quantities. | 1 |
| 1.7a | 1. (+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, ¦v¦, ¦v¦, v). | 1 |
| 1.7b | 2. (+) Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point. | 1 |
| 1.7c | 3. (+) Solve problems involving velocity and other quantities that can be represented by vectors. | 2 |
| 1.8 | Perform operations on vectors. | 1 |
| 1.8a | 4. (+) Add and subtract vectors. | 1 |
| 1.8b | a. Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes. | 2 |
| 1.8c | b. Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum. | 1 |
| 1.8d | c. Understand vector subtraction v – w as v + (-w), where –w is the additive inverse of w. with the same magnitude as w and pointing in the opposite direction. Represent vector subtraction graphically by connecting the tips in the appropriate order, and perform, vector subtraction component-wise. | 1 |
| 1.8e | 5. (+) Multiply a vector by a scalar. | 1 |
| 1.8f | a. Represent scalar multiplication graphically by scaling vectors and possibly reversing their direction; perform scalar multiplication component-wise, e.g., as c(vx, vy) = (cvx, cvy). | 1 |
| 1.8g | b. Compute the magnitude of a scalar multiple cv using ¦cv¦ = ¦c¦v. Compute the direction of cv knowing that when ¦c¦v ? 0, the direction of cv is either along v (for c>0) or against v (for c<0). | 1 |
| 1.9 | Perform operations on matrices and use matrices in applications. | 2 |
| 1.9a | 6. (+) Use matrices to represent and manipulate data, e.g., to represent payoffs or incidence relationships in a network. | 2 |
| 1.9b | 7. (+) Multiply matrices by scalars to produce new matrices, e.g., as when all of the payoffs in a | 1 |

| Level | Description | DOK |
|---|---|---|
| | game are doubled. | |
| 1.9c | 8. (+) Add, subtract, and multiply matrices of appropriate dimensions. | 1 |
| 1.9d | 9. (+) Understand that, unlike multiplication of numbers, matric multiplication for square matrices is not a commutative operation, but still satisfies the associative and distributive properties. | 2 |
| 1.9e | 10. (+) Understand that the zero and identity matrices play a role in matrix addition and multiplication similar to the role of 0 and 1 in the real numbers. The determinant of square matrix is nonzero if and only if the matrix has a multiplicative inverse. | 2 |
| 1.9f | 11. (+) Multiply a vector (regarded as a matrix with one column) by a matrix of suitable dimensions to produce another vector. Work with matrices as transformations of vectors. | 2 |
| 1.9g | 12. (+) Work with 2 x 2 matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area. | 2 |
| 2 | Algebra | 2 |
| 2.1 | Interpret the structure of expressions | 2 |
| 2.1a | 1. Interpret expressions that represent a quantity in terms of its content.* | 2 |
| 2.1b | a. Interpret parts of an expression, such as terms, factors, and coefficients.* | 2 |
| 2.1c | b. Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret P(1 = r)n as the product of P and a factor not depending on P.* | 2 |
| 2.1d | 2. Use the structure of an expression to identify ways to rewrite it. For example, see x4 – y4 as (x2)2 – (y2)2, thus recognizing it as a difference of squares that can be factored as (x2 – y2)(x2 + y2). | 2 |
| 2.2 | Write expressions in equivalent forms to solve problems. | 2 |
| 2.2a | 3. Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.* | 3 |
| 2.2b | a. Factor a quadratic expression to reveal the zeros of the function it defines.* | 1 |
| 2.2c | b. Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.* | 1 |
| 2.2d | c. use the properties of exponents to transform expressions for exponential functions. For example, the expression 1.15t can be rewritten as (1.151/12)12t ˜ 1.01212t to reveal the approximate equivalent monthly interest rate if the annual rate is 15%.* | 2 |
| 2.2e | 4. Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems. For example, calculate mortgage payments.* | 2 |
| 2.3 | Perform arithmetic operations on polynomials | 1 |
| 2.3a | 1. Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials. | 1 |

| Level | Description | DOK |
|---|---|---|
| 2.4 | Understand the relationship between zeros and factors of polynomials. | 2 |
| 2.4a | 2. Know and apply the Remainder Theorem: For a polynomial p(x) and a number a, the remainder on division by x – a is p(a), so p(a) = 0 if and only if (x – a) is a factor of p(x). | 1 |
| 2.4b | 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. | 2 |
| 2.5 | Use polynomial identities to solve problems. | 3 |
| 2.5a | 4. Prove polynomial identities and use them to describe numerical relationships. For example, the polynomial identity (x2 + y2)2 = (x2 – y2)2 + (2xy)2 can be used to generate Pythagorean triples. | 3 |
| 2.5b | 5. (Know and apply the Binomial Theorem for the expansion of (x + y)n in powers of x and y for a positive integer n, where x and y are any numbers, with coefficients determined for example by Pascal's Triangle.1 | 1 |
| 2.6 | Rewrite rational expressions. | 2 |
| 2.6a | 6. Rewrite simple rational expressions in different forms; write a(x)/b(x) in the form q(x) + r(x)/b(x), where a(x), b(x),q(x), and r(x) are polynomials with the degree of r(x) less than the degree of b(x), using inspection, long division, or, for the more complicated examples, a computer algebra system. | 2 |
| 2.6b | 7. (+) Understand that rational expressions form a system analogous to the rational numbers, closed under addition, subtraction, multiplication, and division by a nonzero rational expression; add, subtract, multiply, and divide rational expressions. | 2 |
| 2,7 | Create equations that describe numbers or relationships. | 3 |
| 2.7a | 1. Create equations and inequalities in one variable including ones with absolute value and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions. CA* | 3 |
| 2.7b | 2. Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.* | 3 |
| 2.7c | 3. Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. For example, represent inequalities describing nutritional and cost constraints on combinations of different foods.* | 3 |
| 2.7d | 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.* | 2 |
| 2.8 | Understand solving equations as a process of reasoning and explain the reasoning. | 3 |
| 2.8a | 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. | 2 |

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| 2.8b | 2. Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise. | 3 |
| 2.9 | Solve equations and inequalities in one variable. | 1 |
| 2.9a | 3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. | 1 |
| 2.9b | 3.1 Solve one-variable equations and inequalities involving absolute value, graphing the solutions and interpreting them in context. CA | 2 |
| 2.9c | 4. Solve quadratic equations in one variable. | 1 |
| 2.9d | a. Use the method of completing the square to transform any quadratic equation in x into an equation of the form (x – p)2 = q that has the same solutions. Derive the quadratic formula from this form. | 1 |
| 2.9e | b. Solve quadratic equations by inspection (e.g., for x2 = 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. | 2 |
| 2.10 | Solve systems of equations. | 2 |
| 2.10a | 5. Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions. | 2 |
| 2.10b | 6. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables. | 2 |
| 2.10c | 7. Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. For example, find the points of intersection between the line y = -3x and the circle x2 = y2 = 3. | 2 |
| 2.10d | 8. (+) Represent a system of linear equations as a single matrix equation in a vector variable. | 1 |
| 2.10e | 9. (+) Find the inverse of a matrix if it exists and use it to solve systems of linear equations (using technology for matrices of dimensions 3 x 3 or greater). | 1 |
| 2.11 | Represent and solve equations and inequalities graphically. | 2 |
| 2.11a | 10. Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line). | 2 |
| 2.11b | 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 tablets 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.* | 2 |
| 2.11c | 12. Graph the solutions to a linear inequality in two variables as a half-plane (excluding the | 1 |

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| | boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes. | |
| 3 | Interpreting Functions | 2 |
| 3.1 | Understanding the concept of a function and use function notation. | 2 |
| 3.1a | 1. Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If f is a function and x is an element of its domain, then f(x) denotes the output of f corresponding to the input x. The graph of f is the graph of the equation y = f(x). | 2 |
| 3.1b | 2. Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context. | 2 |
| 3.1c | 3. Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. For example, the Fibonacci sequence is defined recursively by f(0) = f(1) = 1, f(n+1) = f(n) + f(n-1) for n = 1. | 2 |
| 3.2 | Interpret functions that arise in applications in terms of the context. | 2 |
| 3.2a | 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. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity.* | 3 |
| 3.2b | 5. Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. For example, if the function h 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.* | 2 |
| 3.2c | 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.* | 2 |
| 3.3 | Analyze functions using different representations. | 2 |
| 3.3a | 7. Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.* | 3 |
| 3.3b | a. Graph linear and quadratic functions and show intercepts, maxima, and minima.* | 2 |
| 3.3c | b. Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.* | 2 |
| 3.3d | c. Graph polynomial functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.* | 2 |
| 3.3e | d. (+) Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.* | 2 |

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| 3.3f | e. Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.* | 2 |
| 3.3g | 8. Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function. | 3 |
| 3.3h | a. Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context. | 3 |
| 3.3i | b. Use the properties of exponents to interpret expressions for exponential functions. For example, identify percent rate of change in functions such as y = (102)t, y = (0.97)t, y = (1.01)12t, y = (1.2)t/10, and classify them as representing exponential growth or decay. | 2 |
| 3.3j | 9. Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum. | 3 |
| 3.3k | 10. (+) Demonstrate an understanding of functions and equations defined parametrically and graph them. CA* | 2 |
| 3.3l | 11. (+) Graph polar coordinates and curves. Convert between polar and rectangular coordinate systems. CA | 2 |
| 3.4 | Build a function that models a relationship between two quantities. | 2 |
| 3.4a | 1. Write a function that describes a relationship between two quantities.* | 4 |
| 3.4b | a. Determine an explicit expression, a recursive process, or steps for calculation from a context.* | 2 |
| 3.4c | b. Combine standard function types using arithmetic operations. For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.* | 2 |
| 3.4d | c. (+) Compose functions. For example, it T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t) is the temperature at the location of the weather balloon as a function of time.* | 2 |
| 3.4e | 2. Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.* | 3 |
| 3.5 | Build new functions from existing functions. | 2 |
| 3.5a | 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. Include recognizing even and odd functions from their graphs and algebraic expressions for them. | 3 |
| 3.5b | 4. Find inverse functions. | 2 |
| 3.5c | a. Solve an equation of the form f(x) = c for a simple function f that has an inverse and write an expression for the inverse. For example, f(x) = 2 x3 or f(x) = (x + 1)/(x-1)for x ?1. | 2 |

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| 3.5d | b. (+) Verify by composition that one function is the inverse of another. | 1 |
| 3.5e | c. (+) read values of an inverse function from a graph or a table, given that the function has an inverse. | 2 |
| 3.5f | d. (+) Produce an invertible function from a non-invertible function by restricting the domain. | 2 |
| 3.5g | 5. (+) Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents. | 2 |
| 3.6 | Construct and compare linear, quadratic, and exponential models and solve problems. | 2 |
| 3.6a | 1. Distinguish between situations that can be modeled with linear functions and with exponential functions.* | 3 |
| 3.6b | a. Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.* | 2 |
| 3.6c | b. Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.* | 2 |
| 3.6d | c. Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another. | 2 |
| 3.6e | 2. Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).* | 2 |
| 3.6f | 3. Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.* | 2 |
| 3.6g | 4. For exponential models, express as a logarithm the solution to abct = d where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.* | 2 |
| 3.6h | 4.1 Prove simple laws of logarithms. CA* | 3 |
| 3.6i | 4.2 Use the definition of logarithms to translate between logarithms in any base. CA* | 2 |
| 3.6j | 4.3 Understand and use the properties of logarithms to simplify logarithmic numeric expressions and to identify their approximate values. CA* | 2 |
| 3.7 | Interpret expressions for functions in terms of the situation they model. | 2 |
| 3.7a | 5. Interpret the parameters in a linear or exponential function in terms of a context.* | 2 |
| 3.7b | 6. Apply quadratic functions to physical problems, such as the motion of an object under the force of gravity. CA* | 2 |
| 3.8 | Extend the domain of trigonometric functions using the unit circle. | 1 |
| 3.8a | 1. Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle. | 1 |
| 3.8b | 2. Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise | 2 |

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| | around the unit circle. | |
| 3.8c | 2.1 Graph all 6 basic trigonometric functions. CA | 1 |
| 3.8d | (+) Use special triangles to determine geometrically the values of sine, cosine, tangent, for p/3, p/4 and p /6, and use the unit circle to express the values of sine, cosine, and tangent for px, p+x, and 2px in terms of their values for x, where x is any real number. | 1 |
| 3.8e | 4. (+) Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions. | 2 |
| 3.9 | Model periodic phenomena with trigonometric functions. | 2 |
| 3.9a | 5. Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.* | 3 |
| 3.9b | 6. (+) Understand that restricting a trigonometric function to a domain on which it is always increasing or always decreasing allows its inverse to be constructed. | 2 |
| 3.9c | 7. (+) Use the inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context.* | 2 |
| 3.10 | Prove and apply trigonometric identities. | 3 |
| 3.10a | 8. Prove the Pythagorean identity sin2 (T) + cos2 (T) = 1 and use it to find sin (T), cos (T), or tan (T) given sin (T), cos (T), or tan (T) and the quadrant of the angle. | 2 |
| 3.10b | 9. (+) Prove the addition and subtraction formulas for sine, cosine, and tangent and use them to solve problems. | 3 |
| 3.10c | 10. (+) Prove the half angle and double angle identities for sine and cosine and use them to solve problems. CA | 3 |
| 4 | Geometry | 3 |
| 4.1 | Experiment with transformations in the plane. | 2 |
| 4.1a | 1. Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc. | 1 |
| 4.1b | 2. Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take point in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch). | 2 |
| 4.1c | 3. Given a rectangle, parallelogram, trapezoid, or regular polygon, describe the rotations and reflections that carry it onto itself. | 2 |
| 4.1d | 4. Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments. | 3 |
| 4.1e | Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure | 3 |

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| | using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another. | |
| 4.2 | Understand congruence in terms of rigid motions. | 3 |
| 4.2a | 6. Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent. | 3 |
| 4.2b | 7. Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent. | 3 |
| 4.2c | 8. Explain how the criteria for triangle congruence (ASA, SAS, and SSS) follow from the definition of congruence in terms of rigid motions. | 3 |
| 4.3 | Prove geometric theorems. | 3 |
| 4.3a | Prove theorems about lines and angles. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints. | 3 |
| 4.3b | Prove theorems about triangles. Theorems include: measures of interior angles of a triangle sum to 180°; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point. | 3 |
| 4.3c | 11. Prove theorems about parallelograms. Theorems include: opposite sides are congruent, opposite angles are congruent, the diagonals of a parallelogram bisect each other and conversely, rectangles are parallelograms with congruent angles. | 3 |
| 4.4 | Make geometric constructions, | 2 |
| 4.4a | 12. Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line. | 2 |
| 4.4b | 13. Construct an equilateral triangle, a square, and a regular hexagon inscribed in a circle. | 2 |
| 4.5 | Understand similarity in terms of similarity transformations. | 2 |
| 4.5a | 1. Verify experimentally the properties of dilations given by a center and a scale factor: | 2 |
| 4.5b | a. A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged. | 2 |
| 4.5c | b. The dilation of a line segment is longer or shorter in the ratio given by the scale factor. | 2 |

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| 4.5d | 2. Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides. | 3 |
| 4.5e | 3. Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar. | 3 |
| 4.6 | Prove theorems involving similarity. | 3 |
| 4.6a | 4. Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity. | 3 |
| 4.6b | 5. Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures. | 3 |
| 4.7 | Define trigonometric ratios and solve problems involving right triangles. | 3 |
| 4.7a | 6. Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles. | 3 |
| 4.7b | 7. Explain and use the relationship between the sine and cosine of complementary angles. | 2 |
| 4.7c | 8. Use trigonometric ratios and the Pythagorean theorem to solve right triangles in applied problems.* | 2 |
| 4.7d | 8.1 Derive and use the trigonometric ratios for special right triangles (30°, 60°, 90°, and 45°, 45°, 90°). CA | 3 |
| 4.8 | Apply trigonometry to general triangles. | 3 |
| 4.8a | 9. (+) Derive the formula A = 1/2ab sin (C) for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side. | 3 |
| 4.8b | 10. (+) Prove the Laws of Sines and Cosines and use them to solve problems. | 3 |
| 4.8c | 11. (+) Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces). | 2 |
| 4.9 | Understand and apply theorems about circles. | 3 |
| 4.9a | 1. Prove that all circles are similar. | 3 |
| 4.9b | 2. Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle. | 2 |
| 4.9c | 3. Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle. | 3 |
| 4.9d | 4. (+) Construct a tangent line from a point outside a given circle to the circle. | 2 |

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| 4.10 | Find arc lengths and areas of sectors of circles. | 3 |
| 4.10a | 5. Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector. Convert between degrees and radians. CA | 3 |
| 4.11 | Translate between the geometric description and the equation for a conic section. | 3 |
| 4.11a | 1. Derive the equation of a circle of given center and radius using the Pythagorean theorem; complete the square to find the center and radius of a circle given by an equation. | 2 |
| 4.11b | 2. Derive the equation of a parabola given a focus and directrix. | 3 |
| 4.11c | 3. (+) Derive the equations of ellipses and hyperbolas given the foci, using the fact that the sum or differences of distances from the foci is constant. | 3 |
| 4.11d | 3.1 Given a quadratic equation of the form ax2 + by2 + cx + dy + e = 0, use the method for completing the square to put the equation into standard form; identify whether the graph of the equation is a circle, ellipse, parabola, or hyperbola and graph the equation. CA | 2 |
| 4.12 | Use coordinates to prove simple geometric theorems algebraically. | 2 |
| 4.12a | 4. use coordinates to prove simple geometric theorems algebraically. For example, prove or disprove that a figure is defined by four given points in the coordinate plane is a rectangle; prove or disprove that the point (1, v3) lies on the circle centered at the origin and containing the point (0, 2). | 3 |
| 4.12b | 5. Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point) | 2 |
| 4.12c | 6. Find the point on a directed line segment between two given points that partitions the segment in a given ratio. | 2 |
| 4.12d | 7. Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula.* | 1 |
| 4.13 | Explain volume formulas and use them to solve problems. | 3 |
| 4.13a | 1. Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. Use dissection arguments, Cavalieri’s principle, and information limit arguments. | 3 |
| 4.13b | 2. (+) Give an informal argument using Cavalieri’s principle for the formulas for the volume of a sphere and other solid figures. | 3 |
| 4.13c | 3. Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.* | 2 |
| 4.14 | Visualize relationships between two-dimensional and three-dimensional objects. | 3 |
| 4.14a | 4. Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects. | 3 |

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| 4.14b | 5. Know that the effect of a scale factor k greater than zero on length, area, and volume is to multiply each by k, k2, and k3, respectively; determine length, area and volume measures using scale factors. CA* | 2 |
| 4.14c | 6. Verify experimentally that in a triangle, angles opposite longer sides are larger, sides opposite larger angles are longer, and the sum of any two side lengths is greater than the remaining side length; apply these relationships to solve real-world and mathematical problems. CA | 3 |
| 4.15 | Apply geometric concepts in modeling situations. | 3 |
| 4.15a | 1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).* | 3 |
| 4.15b | 2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).* | 3 |
| 4.15c | 3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).* | 3 |
| 5 | Statistics and Probability | 3 |
| 5.1 | Summarize, represent, and interpret data on a single count or measurement variable. | 3 |
| 5.1a | 1. Represent data with plots on the real number line (dot plots, histograms, and box plots).* | 1 |
| 5.1b | 2. Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets.* | 2 |
| 5.1c | 3. Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).* | 3 |
| 5.1d | 4. Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.* | 3 |
| 5.2 | Summarize, represent, and interpret data on two categorical and quantitative variables. | 3 |
| 5.2a | 5. Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.* | 3 |
| 5.2b | 6. Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.* | 2 |
| 5.2c | 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.* | 3 |
| 5.2d | b. Informally assess the fit of a function by plotting and analyzing residuals.* | 3 |
| 5.2e | c. Fit a linear function for a scatter plot that suggests a linear association.* | 2 |

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| 5.3 | Interpret linear models. | 2 |
| 5.3a | 7. Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.* | 2 |
| 5.3b | 8. Compute (using technology) and interpret the correlation coefficient of a linear fit.* | 2 |
| 5.3c | 9. Distinguish between correlation and causation.* | 3 |
| 5.4 | Understand and evaluate random processes underlying statistical experiments. | 3 |
| 5.4a | 1. Understand statistics as a process for making inferences about population parameters based on a random sample from that population.* | 3 |
| 5.4b | 2. Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. For example, a model says a spinning coin falls heads up with probability o.5. Would a result of 5 tails in a row cause you to question the model?* | 3 |
| 5.5 | Make inferences and justify conclusions from sample surveys, experiments, and observational studies. | 3 |
| 5.5a | 3. Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization related to each.* | 3 |
| 5.5b | 4. Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling. | 2 |
| 5.5c | 5. Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.* | 3 |
| 5.5d | 6. Evaluate reports based on data.* | 3 |
| 5.6 | Understand independence and conditional probability and use them to interpret data. | 2 |
| 5.6a | 1. Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not").* | 2 |
| 5.6b | 2. Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.* | 2 |
| 5.6c | 3. Understand the conditional probability of A given B as P(A and B)/P(B), and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.* | 2 |
| 5.6d | 4. Construct and interpret two-way frequency tables of data when two categories are associated with each other being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given | 2 |

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| | that the student is in tenth grade. Do the same for other subjects and compare the results.* | |
| 5.6e | Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.* | 3 |
| 5.7 | Use the rules of probability to compute probabilities of compound events in a uniform probability model. | 2 |
| 5.7a | 6. Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model.* | 2 |
| 5.7b | 7. Apply the Addition Rule, P(A or B) = P(A) + P(B) – P(A and B), and interpret the answer in terms of the model.* | 2 |
| 5.7c | 8. (+) Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)p(B/A) = P(B)P(A/B), and interpret the answer in terms of the model.* | 2 |
| 5.7d | 9. (+) Use permutations and combinations to compute probabilities of compound events and solve problems.* | 2 |
| 5.8 | Calculate expected values and use them to solve problems. | 3 |
| 5.8a | 1. (+) Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions.* | 3 |
| 5.8b | 2. (+) Calculate the expected value of a random variable; interpret it as the mean of the probability distribution.* | 2 |
| 5.8c | 3. (+) Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. For example, find the theoretical probability distribution for the number of correct answers obtained by guessing on all five questions of a multiple-choice test where each question has four choices, and find the expected grade under various grading schemes.* | 3 |
| 5.8d | 4. (+) Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. For example, find a current data distribution on the number of TV sets per household in the United States, and calculate the expected number of sets per household. How many TV sets would you expect to find in 100 randomly selected households?* | 3 |
| 5.9 | Use probability to evaluate outcomes of decisions. | 3 |
| 5.9a | 5. (+) Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values.* | 3 |
| 5.9b | a. Find the expected payoff for a game of change. For example, find the expected winnings from a state lottery ticket or a game at a fast-food restaurant.* | 3 |

| Level | Description | DOK |
|---|---|---|
| 5.9c | b. Evaluate and compare strategies on the basis of expected values. For example, compare a high-deductible versus a low-deductible automobile insurance policy using various, but reasonable, chances of having a minor or a major accident.* | 4 |
| 5.9d | 6. (+) Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).* | 2 |
| 5.9e | 7. (+) Analyze decisions and strategies using probability concepts (e.g. product testing, medical testing, pulling a hockey goalie at the end of a game).* | 4 |

# APPENDIX F: ITEM AGREEMENT REPORT

*(Objective/Item Number: Number of Reviewers)*

| Low | | Medium | | High |
|---|---|---|---|---|
| 1 | | 3 | | 7 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6:1 | 10:1 | 13:1 | 15:1 | | | | | | | | | |
| 1.1 | 20:1 | | | | | | | | | | | | |
| 1.1a | 19:1 | 25:1 | 40:1 | | | | | | | | | | |
| 1.1b | 19:1 | 20:1 | 25:1 | 40:2 | | | | | | | | | |
| 1.2 | 22:1 | | | | | | | | | | | | |
| 1.2a | 3:1 | 19:1 | | | | | | | | | | | |
| 1.3 | | | | | | | | | | | | | |
| 1.3a | 7:1 | 9:1 | 11:3 | 12:1 | 13:2 | 17:1 | 21:1 | 30:1 | 33:1 | 36:2 | 37:1 | 46:2 | 49:1 |
| | 50:1 | | | | | | | | | | | | |
| 1.3b | 49:1 | | | | | | | | | | | | |
| 1.3c | | | | | | | | | | | | | |
| 1.4 | | | | | | | | | | | | | |
| 1.4a | | | | | | | | | | | | | |
| 1.4b | | | | | | | | | | | | | |
| 1.4c | | | | | | | | | | | | | |
| 1.5 | | | | | | | | | | | | | |
| 1.5a | | | | | | | | | | | | | |
| 1.5b | | | | | | | | | | | | | |
| 1.5c | | | | | | | | | | | | | |
| 1.6 | | | | | | | | | | | | | |
| 1.6a | | | | | | | | | | | | | |
| 1.6b | | | | | | | | | | | | | |
| 1.6c | | | | | | | | | | | | | |
| 1.7 | | | | | | | | | | | | | |
| 1.7a | | | | | | | | | | | | | |
| 1.7b | | | | | | | | | | | | | |
| 1.7c | | | | | | | | | | | | | |
| 1.8 | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|
| 1.8a | | | | | | | | |
| 1.8b | | | | | | | | |
| 1.8c | | | | | | | | |
| 1.8d | | | | | | | | |
| 1.8e | | | | | | | | |
| 1.8f | | | | | | | | |
| 1.8g | | | | | | | | |
| 1.9 | | | | | | | | |
| 1.9a | | | | | | | | |
| **1.9b** | | | | | | | | |
| 1.9c | | | | | | | | |
| 1.9d | | | | | | | | |
| 1.9e | | | | | | | | |
| 1.9f | | | | | | | | |
| 1.9g | | | | | | | | |
| 2 | | | | | | | | |
| 2.1 | | | | | | | | |
| 2.1a | 25:1 | | | | | | | |
| 2.1b | 1:1 | 2:1 | 16:1 | | | | | |
| 2.1c | | | | | | | | |
| 2.1d | 2:1 | 18:2 | | | | | | |
| 2.2 | | | | | | | | |
| 2.2a | 1:1 | 2:2 | 16:1 | 18:2 | 27:1 | 28:2 | 36:1 | 41:1 |
| 2.2b | | | | | | | | |
| 2.2c | | | | | | | | |
| 2.2d | | | | | | | | |
| 2.2e | 16:1 | | | | | | | |
| 2.3 | | | | | | | | |
| 2.3a | 5:1 | 16:4 | 18:1 | 19:1 | 43:1 | | | |
| 2.4 | | | | | | | | |
| 2.4a | | | | | | | | |
| 2.4b | | | | | | | | |
| 2.5 | | | | | | | | |
| 2.5a | 2:1 | | | | | | | |

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|---|---|---|---|---|---|---|---|
| 2.5b | | | | | | | |
| 2.6 | | | | | | | |
| 2.6a | 18:3 | 28:1 | | | | | |
| 2.6b | 28:2 | | | | | | |
| 2,7 | | | | | | | |
| 2.7a | 23:1 | 33:1 | 36:2 | 37:3 | 38:1 | 41:3 | 45:1 |
| 2.7b | 30:1 | | | | | | |
| 2.7c | | | | | | | |
| 2.7d | 27:2 | | | | | | |
| 2.8 | | | | | | | |
| 2.8a | 11:1 | | | | | | |
| 2.8b | 19:2 | 25:2 | 27:1 | | | | |
| 2.9 | | | | | | | |
| 2.9a | 2:1 | 19:1 | 27:2 | 30:1 | 33:1 | 37:2 | 45:1 |
| 2.9b | 2:1 | 5:1 | 38:4 | | | | |
| 2.9c | | | | | | | |
| 2.9d | | | | | | | |
| 2.9e | | | | | | | |
| 2.10 | | | | | | | |
| 2.10a | | | | | | | |
| 2.10b | 49:4 | 50:3 | | | | | |
| 2.10c | | | | | | | |
| 2.10d | | | | | | | |
| 2.10e | | | | | | | |
| 2.11 | | | | | | | |
| 2.11a | 8:1 | 26:1 | 46:1 | | | | |
| 2.11b | | | | | | | |
| 2.11c | 8:1 | | | | | | |
| 3 | | | | | | | |
| 3.1 | | | | | | | |
| 3.1a | 35:2 | | | | | | |
| 3.1b | 25:3 | 26:5 | 35:3 | 43:5 | | | |
| 3.1c | | | | | | | |
| 3.2 | | | | | | | |

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|---|---|---|---|
| 3.2a | 46:1 | | |
| 3.2b | | | |
| 3.2c | | | |
| 3.3 | | | |
| 3.3a | 36:1 | | |
| 3.3b | 8:2 | 42:1 | 46:1 |
| 3.3c | | | |
| 3.3d | | | |
| 3.3e | | | |
| 3.3f | | | |
| 3.3g | | | |
| 3.3h | | | |
| 3.3i | | | |
| 3.3j | | | |
| 3.3k | | | |
| 3.3l | | | |
| 3.4 | | | |
| 3.4a | 23:1 | 41:1 | |
| 3.4b | 36:1 | 41:2 | 50:1 |
| 3.4c | | | |
| 3.4d | 43:2 | | |
| 3.4e | | | |
| 3.5 | | | |
| 3.5a | 8:3 | | |
| 3.5b | | | |
| 3.5c | | | |
| 3.5d | | | |
| 3.5e | | | |
| 3.5f | | | |
| 3.5g | | | |
| 3.6 | | | |
| 3.6a | | | |
| 3.6b | 50:1 | | |
| 3.6c | 46:1 | | |

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|---|---|
| 3.6d | |
| 3.6e | |
| 3.6f | |
| 3.6g | |
| 3.6h | |
| 3.6i | |
| 3.6j | |
| 3.7 | |
| 3.7a | |
| 3.7b | |
| 3.8 | |
| 3.8a | |
| 3.8b | |
| 3.8c | |
| 3.8d | |
| 3.8e | |
| 3.9 | |
| 3.9a | |
| 3.9b | |
| 3.9c | |
| 3.10 | |
| 3.10a | |
| 3.10b | |
| 3.10c | |
| 4 | |
| 4.1 | |
| 4.1a | 9:1 |
| 4.1b | |
| 4.1c | |
| 4.1d | |
| 4.1e | |
| 4.2 | |
| 4.2a | |
| 4.2b | |

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|---|---|---|---|
| 4.2c | | | |
| 4.3 | | | |
| 4.3a | 9:2 | 17:2 | 39:1 |
| 4.3b | 7:1 | 39:2 | 45:1 |
| 4.3c | 7:1 | 21:1 | |
| 4.4 | | | |
| 4.4a | | | |
| 4.4b | | | |
| 4.5 | | | |
| 4.5a | | | |
| 4.5b | | | |
| 4.5c | | | |
| 4.5d | | | |
| 4.5e | | | |
| 4.6 | | | |
| 4.6a | 42:1 | 45:1 | |
| 4.6b | 7:2 | | |
| 4.7 | | | |
| 4.7a | | | |
| 4.7b | | | |
| 4.7c | 21:1 | | |
| 4.7d | 45:1 | | |
| 4.8 | | | |
| 4.8a | | | |
| 4.8b | | | |
| 4.8c | | | |
| 4.9 | | | |
| 4.9a | | | |
| 4.9b | 12:1 | | |
| 4.9c | | | |
| 4.9d | | | |
| 4.10 | 48:2 | | |
| 4.10a | 49:1 | | |
| 4.11 | | | |

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|---|---|---|---|---|---|
| 4.11a | | | | | |
| 4.11b | 8:1 | | | | |
| 4.11c | | | | | |
| 4.11d | | | | | |
| 4.12 | | | | | |
| 4.12a | | | | | |
| 4.12b | 42:1 | | | | |
| 4.12c | | | | | |
| 4.12d | 32:1 | 42:2 | | | |
| 4.13 | | | | | |
| 4.13a | 12:1 | 48:1 | | | |
| 4.13b | | | | | |
| 4.13c | | | | | |
| 4.14 | | | | | |
| 4.14a | | | | | |
| 4.14b | | | | | |
| 4.14c | | | | | |
| 4.15 | | | | | |
| 4.15a | | | | | |
| 4.15b | | | | | |
| 4.15c | | | | | |
| 5 | | | | | |
| 5.1 | 6:1 | 31:1 | | | |
| 5.1a | 1:1 | 29:3 | 30:1 | 33:1 | 47:3 |
| 5.1b | 6:1 | 29:2 | 33:2 | 47:1 | |
| 5.1c | 29:1 | | | | |
| 5.1d | | | | | |
| 5.2 | | | | | |
| 5.2a | 15:1 | | | | |
| 5.2b | 30:1 | | | | |
| 5.2c | | | | | |
| 5.2d | | | | | |
| 5.2e | | | | | |
| 5.3 | | | | | |

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|---|---|
| 5.3a | 46:2 |
| 5.3b | |
| 5.3c | |
| 5.4 | |
| 5.4a | 31:1 |
| 5.4b | |
| 5.5 | |
| 5.5a | 31:1 |
| 5.5b | 31:2 |
| 5.5c | |
| 5.5d | |
| 5.6 | |
| 5.6a | |
| 5.6b | |
| 5.6c | |
| 5.6d | |
| 5.6e | |
| 5.7 | |
| 5.7a | |
| 5.7b | |
| 5.7c | |
| 5.7d | |
| 5.8 | |
| 5.8a | |
| 5.8b | |
| 5.8c | |
| 5.8d | |
| 5.9 | |
| 5.9a | |
| 5.9b | |
| 5.9c | |
| 5.9d | |
| 5.9e | |

# APPENDIX G: ITEM AGREEMENT COVERAGE

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2.1b:1 | 2.2a:1 | 5.1a:1 | | | |
| 2 | 2.1b:1 | 2.1d:1 | 2.2a:2 | 2.5a:1 | 2.9a:1 | 2.9b:1 |
| 3 | 1.2a:1 | | | | | |
| 4 Field test item | | | | | | |
| 5 | 2.3a:1 | 2.9b:1 | | | | |
| 6 | 1:1 | 5.1:1 | 5.1b:1 | | | |
| 7 | 1.3a:1 | 4.3b:1 | 4.3c:1 | 4.6b:2 | | |
| 8 | 2.11a:1 | 2.11c:1 | 3.3b:2 | 3.5a:3 | 4.11b:1 | |
| 9 | 1.3a:1 | 4.1a:1 | 4.3a:2 | | | |
| 10 | 1:1 | | | | | |
| 11 | 1.3a:3 | 2.8a:1 | | | | |
| 12 | 1.3a:1 | 4.9b:1 | 4.13a:1 | | | |
| 13 | 1:1 | 1.3a:2 | | | | |
| 14 Field test item | | | | | | |
| 15 | 1:1 | 5.2a:1 | | | | |
| 16 | 2.1b:1 | 2.2a:1 | 2.2e:1 | 2.3a:4 | | |
| 17 | 1.3a:1 | 4.3a:2 | | | | |
| 18 | 2.1d:2 | 2.2a:2 | 2.3a:1 | 2.6a:3 | | |
| 19 | 1.1a:1 | 1.1b:1 | 1.2a:1 | 2.3a:1 | 2.8b:2 | 2.9a:1 |
| 20 | 1.1:1 | 1.1b:1 | | | | |
| 21 | 1.3a:1 | 4.3c:1 | 4.7c:1 | | | |
| 22 | 1.2:1 | | | | | |
| 23 | 2.7a:1 | 3.4a:1 | | | | |
| 24 Field test item | | | | | | |
| 25 | 1.1a:1 | 1.1b:1 | 2.1a:1 | 2.8b:2 | 3.1b:3 | |
| 26 | 2.11a:1 | 3.1b:5 | | | | |
| 27 | 2.2a:1 | 2.7d:2 | 2.8b:1 | 2.9a:2 | | |
| 28 | 2.2a:2 | 2.6a:1 | 2.6b:2 | | | |
| 29 | 5.1a:3 | 5.1b:2 | 5.1c:1 | | | |
| 30 | 1.3a:1 | 2.7b:1 | 2.9a:1 | 5.1a:1 | 5.2b:1 | |
| 31 | 5.1:1 | 5.4a:1 | 5.5a:1 | 5.5b:2 | | |
| 32 | 4.12d:1 | | | | | |
| 33 | 1.3a:1 | 2.7a:1 | 2.9a:1 | 5.1a:1 | 5.1b:2 | |
| 34 Field test item | | | | | | |
| 35 | 3.1a:2 | 3.1b:3 | | | | |
| 36 | 1.3a:2 | 2.2a:1 | 2.7a:2 | 3.3a:1 | 3.4b:1 | |
| 37 | 1.3a:1 | 2.7a:3 | 2.9a:2 | | | |
| 38 | 2.7a:1 | 2.9b:4 | | | | |
| 39 | 4.3a:1 | 4.3b:2 | | | | |
| 40 | 1.1a:1 | 1.1b:2 | | | | |
| 41 | 2.2a:1 | 2.7a:3 | 3.4a:1 | 3.4b:2 | | |
| 42 | 3.3b:1 | 4.6a:1 | 4.12b:1 | 4.12d:2 | | |

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|---|---|---|---|---|---|---|
| 43 | 2.3a:1 | 3.1b:5 | 3.4d:2 | | | |
| 44 Field test item | | | | | | |
| 45 | 2.7a:1 | 2.9a:1 | 4.3b:1 | 4.6a:1 | 4.7d:1 | |
| 46 | 1.3a:2 | 2.11a:1 | 3.2a:1 | 3.3b:1 | 3.6c:1 | 5.3a:2 |
| 47 | 5.1a:3 | 5.1b:1 | | | | |
| 48 | 4.10:2 | 4.13a:1 | | | | |
| 49 | 1.3a:1 | 1.3b:1 | 2.10b:4 | 4.10a:1 | | |
| 50 | 1.3a:1 | 2.10b:3 | 3.4b:1 | 3.6b:1 | | |

# APPENDIX H: SOURCE OF CHALLENGE ISSUES

| Item Number | Comments by Reviewer |
|---|---|
| 1 | It is a word problem, requiring relating values to portions of circles. |
| 3 | Sixth Grade Prerequisite Standard |
| 5 | The presence of absolute values and a fraction may be challenging. |
| 6 | The presence of words may make this problem challenging. |
| 7 | There is a lot to read and connect for this problem. |
| 10 | Adding fractions in context may create a challenge. |
| 11 | The word problem nature of this problem may make it challenging. |
| 13 | The word problem and table may cause challenges for students. |
| 15 | It is a word problem. |
| 18 | Fractions and factoring can be challenging. |
| 19 | Fractions and radicals can be challenging. |
| 20 | Fractions and exponents |
| 21 | This has words and multiples skills needed to solve (drawing a picture, using the Pythagorean theorem and finding perimeter). |
| 22 | Ordering fractions is difficult |
| 23 | Word problems and percents are challenging. |
| 25 | Words and radicals. |
| 26 | Connecting graphs to values |
| 27 | Fractions and equations |
| 28 | Fractions |
| 29 | Data analysis can be challenging |
| 30 | This problem is very challenging as students need to solve an equation with percents and in context. |
| 31 | It's a word problem with percents. |
| 32 | This is a middle school problem. |
| 33 | This is a challenging middle school problem involving data analysis involving a word problem. |
| 35 | This is a middle school task. |
| 36 | This is a word problem |
| 36 | No standard addresses creating expressions. |
| 37 | It involves percents and is a word problem. |
| 38 | Prerequisite 8th grade knowledge. |
| 38 | It is a linear absolute value inequality.  Very straight forward. |
| 39 | The picture is rather complicated to visualize. |
| 41 | It is a complicated word problem. |
| 42 | It uses geometry ideas and algebra ideas. |
| 45 | It is a word problem and involves ratio.  The I-II-III style is also more involved than a standard MCQ. |

| Item Number | Comments by Reviewer |
| --- | --- |
| 46 | The notion of "tread depth" may discourage students from engaging in the problem. |
| 46 | The word problem also includes a graph that requires analyzing and reading units. |
| 46 | Some test takers may not understand tread depth. |
| 47 | It is an involved histogram and requires understanding how to interpret it. |
| 48 | Students need to first find the radius of the circle and then the area. |
| 49 | It is a word problem. |
| 50 | It is a word problem and a system of equations. |

# APPENDIX I: NOTES BY REVIEWER

| Item Number | Comments by Reviewer |
| --- | --- |
| 1 | This is grade 6 (6.RP.3) |
| 1 | This problem is a middle school level problem. |
| 1 | Prerequisite knowledge |
| 1 | The circle graph in this item does not appear to be a high school standard. 5.1a is the closest match |
| 3 | This is grade 5: 5.NBT.7 |
| 3 | This is a middle school level problem. |
| 3 | Prerequisite knowledge |
| 5 | This is a middle school problem. |
| 5 | Prerequisite knowledge |
| 6 | Grade 6: 6.SP.5 |
| 6 | This is a middle school problem. |
| 6 | Prerequisite knowledge |
| 6 | Refers to a specific prerequisite standard but generally fits as a summary of the single variable count. |
| 6 | Finding a simple average of data. Not a high school standard |
| 7 | Grade 7: 7.G.5 |
| 7 | The standard for 4.3b is about proving theorems about triangles. This question uses those theorems (definition of congruence, bisector, and triangle sum theorem). |
| 7 | Geometry standards are above this problem, but quantitative reasoning is fitting. |
| 9 | Grade 7: 7.G.5 |
| 9 | This problem uses theorems about lines and angles, does not prove them. |
| 9 | Geometry standards are above this problem, but quantitative reasoning is fitting. |
| 10 | Prerequisite 7th grade material. |
| 10 | Grade 5: 5.NF.1 |
| 10 | This is a middle school problem. |
| 10 | Prerequisite knowledge |
| 10 | Number and Quantity - a problem involving simple fractions |
| 11 | Grade 7: 7.RP.3 |
| 11 | This problem is barely a high school problem. It may be considered a middle school problem. |
| 11 | Prerequisite knowledge |
| 11 | A problem easily solved with a proportion |
| 12 | Prerequisite knowledge |

| Item Number | Comments by Reviewer |
|---|---|
| 12 | Grade 7: 7.G.4 |
| 12 | This problem is a borderline Middle School and High School problem. |
| 12 | Geometry standards are above this problem, but quantitative reasoning is applicable. |
| 13 | Grade 6: 6.RP.3.c |
| 13 | This problem is barely a high school level problem. |
| 13 | Prerequisite knowledge |
| 13 | Number - simple estimation problem with percentages |
| 15 | Prerequisite 6th grade standard |
| 15 | Grade 6: 6.RP.3.c |
| 15 | This is a middle school problem. |
| 15 | Prerequisite knowledge |
| 15 | Simple number estimating 40% of 3 million |
| 17 | Prerequisite 8th grade standard |
| 17 | Grade 8: 8.G.5 |
| 17 | The standard is about proving relationships between lines and angles, this question uses those relationships. |
| 20 | Seventh grade prerequisite knowledge |
| 20 | Grade 6: 6.EE.1 |
| 20 | This is a middle school problem. |
| 20 | Prerequisite knowledge |
| 20 | Dividing powers of the same base |
| 21 | Prerequisite 8th grade knowledge |
| 21 | Grade 8: 8.G.7, grade 3: 3.MD.8 |
| 21 | This problem is technically a middle school level problem. But I chose the closest HS standard. The high school standard is about proving relationships in parallelograms, this problem has them use the relationships. |
| 21 | Geometric content requires prerequisite knowledge, but quantitative reasoning is applicable. |
| 22 | Prerequisite sixth grade knowlwdge |
| 22 | Grade 4: 4.NF.2 |
| 22 | This is a middle school level problem. |
| 22 | Prerequisite knowledge |
| 22 | simply putting three fractions in order |
| 23 | Prerequisite 7th grade knowledge |
| 23 | Grade 7: 7.RP.3 |
| 23 | This is a challenging middle school level problem, but I chose the closest HS standards |
| 23 | Prerequisite knowledge |
| 28 | Prerequisite knowledge |
| 29 | Grade 6: 6.SP.5.c |

| Item Number | Comments by Reviewer |
|---|---|
| 29 | Prerequisite knowledge |
| 30 | Grade 6: 6.3.c |
| 30 | Prerequisite knowledge |
| 31 | Grade 7: 7.SP.1 |
| 31 | Prerequisite knowledge |
| 31 | A simple stats problem with one set of data. Finding the complement of an event. |
| 32 | Eighth grade prerequisite knowledge |
| 32 | Grade 7: 7.G.6 |
| 32 | Prerequisite knowledge |
| 32 | Does not fit this standard perfectly as no coordinates are used. |
| 35 | Prerequisite knowledge |
| 37 | Grade 6: 6.RP.2 and 6.RP.3.c |
| 37 | Prerequisite knowledge |
| 39 | Grade 7: 7.G.5 |
| 39 | Prerequisite knowledge |
| 40 | Prerequisite 7th grade knowledge |
| 40 | Prerequisite knowledge |
| 40 | Not a perfect match to the standard as it is estimating a radical expression, not repressing it with rational exponents. |
| 42 | Prerequisite 8th grade knowledge |
| 42 | Grade 8: 8.EE.5 |
| 43 | This is a bad fit of assessment to standard, but the closest I could find. |
| 45 | Grade 7: 7.RP.3, Grade 8: 8.G.5 |
| 45 | Prerequisite knowledge |
| 46 | No geometric standards fit, but quantitative reasoning is applicable. |
| 47 | Grade 2: 2.MD.10 |
| 47 | Prerequisite knowledge |
| 47 | I chose DOK 3, as the student does not take a simple sum of the guest totals, but must interpret the graph and multiply guests per student by the number of guests, and then sum these. There is more to this problem than its face value. |
| 48 | Prerequisite eighth grade knowledge. |
| 48 | Grade 7: 7.G.4 and 7.RP.3 |
| 48 | Prerequisite knowledge |
| 48 | Sector area may be used but they are not required to derive the formula as 4.10a states. |
| 48 | 4.10 reads: Find arc length and areas of sectors of circles. DOK 3 as both the circumference formula and the sector area formula must be used together. |
| 50 | Prerequisite knowledge |

# APPENDIX J: DEBRIEFING SUMMARY BY REVIEWER

**A. For each standard, did the items cover the most important topics you expected by the standard? If not, what topics were not assessed that should have been?**

· Many standards were not assessed, several were assessed repeatedly – often from various perspectives. For these that were, the most important topics were well covered. For standards assessed only once, an important aspect was tested.
· Most high school standards were not covered at all. However, many of the CCSSM standards are too specialized to be reasonably designated as needed for all students to be college and career ready.
· I feel that there were many standards that were not tested at all. Many questions seems to be at a basic algebra 1 level. I was very surprised to not see more geometry and algebra 2 based questions.
· Not enough of the standards are covered by the exam. Too many questions use the same standards and too many do not align with any standards because they are prerequisite material.
· I thought the items were lacking in how they addressed the standards. Many of the items addressed standards from previous grades. There was very few items that addressed basic understandings of functions (quadratic, exponential, polynomial, etc.)
· As in aligning any older assessment or textbook to a new set of standards, the test items did not often meet the exact wording of the high school standards. For instance, one asked students to estimate a radical expression, but the standard called for moving between the radical expression and the expression written with rational exponents.

**B. For each standard, did the items cover the most important performance (DOK levels) you expected by the standard? If not, what performance was not assessed?**

· The level 3 and 4 standards were often assessed at level 2. This is understandable in light of the format (5 response multiple choice) and speededness of the assessment
· The (+) standard 3.4d regarding composition of functions was about creating a composition of functions based on a context, whereas the test item only asked for a Level 1 rote procedur.
· I felt that most of the questions were all DOK 1 and 2. I was surprised to not see more DOK 3 questions.
· No. The most basic DOK levels were addressed and none of the higher order.
· Most of the items were, in my opinion, DOK 2. I understand why a test like this would not address too many DOK 4 levels however, I would have expected more

DOK level 3 questions.
· Given that it is a multiple choice test, most of the items were DOK 1 or DOK 2. Some questions were DOK 3, as they required combining several ideas. These types of questions would be better assessed by a written response, as the source of error could be detected. In a multiple choice question, it is simply right or wrong, offering no feedback on the higher level problems.

**C. Were the standards written at an appropriate level of specificity and directed towards expectations appropriate for the grade level?**

· Yes
· No. The CCSSM for high school include many standards that are NOT appropriate to be called COMMON CORE, but rather are important only for some college majors and a small number of careers.
· I felt that too many questions were on middle school standards or basic high school standards.
· Yes.
· I believe the standards are specific and grade level appropriate.
· The CCSS standards are more broadly written than the previous standards which focused primarily on procedures that are easily assessed. CCSS standards also address conceptual learning.

**D. What is your general opinion of the alignment between the standards and assessment:**

iii. Needs slight improvement (4) : 67%
iv. Needs major improvement (2) : 33%

**E. Comments**
· The assessment (appropriately for purposes of placement) addressed a number of important prerequisite topic from grades 6 through 8.
· The questions were aligned to standards. I felt that the depth and variety was lacking.
· The ELM is not appropriately aligned with the state standards.
· I believe the assessment would give valuable DOK 1, 2 information on the student's level. However, DOK 3 or 4 questions should be assessed with a written response. Given CCSS, there should be a written response portion added to the exam, to assess the higher depth of knowledge levels.

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