How Well are Mathematics Common Core Standards Reflected in Mathematics College Readiness Expectations? *RESEARCH*

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Abstract

On February 10, 2010, Kentucky made history by being the first state to adopt the Common Core State Standards (CCSS). The CCSS were designed to be more rigorous, focused, and applicable (Holiday, 2010) than previous standards. The adoption of these standards was predicated by Senate Bill 1, Unbridled Learning. This bill required legislative bodies to develop a unified strategy to reduce the high college remediation rates of recent high school graduates by at least fifty percent before 2014. Along with high schools being required to address underprepared college students, state universities were to align their remediation courses with the new standards. This research study compares content assessed on course finals from Kentucky public universities in highest-level remedial mathematics courses and content assessed on college placement examinations. The study addressed the following two research questions: (1) what mathematical prerequisite knowledge do state universities consider necessary to be college ready? Specifically, 1a) What content domains do the state universities emphasize in their remediation courses?; 1b) Is there consistency across the state public universities with regard to the content domains?; and (2) Is there consistency between Kentucky's mathematics placement assessments (ACT, COMPASS, and KYOTE) and with four-year universities' Kentucky Mathematics College Readiness Expectations (KM-CRE)? Findings suggested that consistency across universities and placement examinations in content emphasis exists. Examinations were heavily weighted in Algebra readiness (Expressions and Equations, Functions, and Algebra).

Keywords: mathematics, common-core standards, mathematics, college readiness

"The likelihood that students will make a successful transition to the college environment is often a function of their readiness—the degree to which previous educational and personal experiences have equipped them for the expectations and demands they will encounter in college" (D. T. Conley, 2008, p. 3). Each year an increasing number of students enter college lacking readiness and are underprepared (Attewell, Lavin, Domina, & Levey, 2006). More and more occupations require a four-year degree and mathematics is often the gatekeeper to higher education. In a concentrated effort to make college success more obtainable for larger numbers of students, each college and university determines specific content knowledge necessary for success in coursework and places that content into a remedial courses (D. T. Conley, 2008). More specifically to adress the mathematical gatekeeper, college administrators and faculty have implemented more mathematics remediation courses to provide students a chance to obtain the necessary content knowledge and college preparedness to successfully complete credit-bearing courses.

Although most colleges offer remediation mathematics courses to help underprepared students, the clear expectation for college preparation is for it to occur in high school. To encourage high schools to embrace the responsibility of college and career readiness, the Kentucky legislature passed Senate Bill 1 in 2009 (Patterson, 2011). Senate Bill 1, entitled 'Unbridled Learning', "…mandated for the Kentucky Council on Postsecondary Education (CPE), the Kentucky Board of Education (KBE), and the Kentucky Department of Education (KDE) to develop a unified strategy to reduce the high college remediation rates of recent high school graduates by at least fifty percent before 2014" ("Senate Bill 1 (2009) College and Career Readiness," 2011). As part of this legislation, new standards for Kentucky schools would need to be adopted, and colleges and universities would need to align

their remediation courses with the new standards.

Intending to increase the number of graduating high school students who are college and career ready, legislative regulations require all students in Kentucky public schools to take the American College Test (ACT) in the spring of their junior year. As mandated by Unbridled Learning, the Kentucky Council on Postsecondary Education determined minimal competency scores for the ACT placement examination to determine college readiness ("Senate Bill 1 (2009) College and Career Readiness," 2011). All Kentucky public postsecondary institutions have adopted the mandated minimal competency score of 19 for mathematics on the ACT. ("Guidelines for admission to the state-supported postsecondary education institutions in Kentucky," 2011). When high school juniors do not obtain this score in mathematics on the ACT, they are required to enroll in a transition mathematics course their senior year ("Minimum requirements for high school graduation," 2011). As a part of Senate Bill 1, a group of secondary and postsecondary mathematics instructors were asked to develop a transitional mathematics course framework in the summer of 2010. This framework embedded Kentucky Core Academic State Standards and college and career readiness standards into a transitional mathematics course.

When students complete the mathematics transition course, students are reassessed using ACT, COMputer-adapted Placement Assessment and Support Services (COMPASS), or KentuckY Online TEsting (KYOTE) placement examinations. The second administration of ACT and any administration of COMPASS are additional expenses to school districts, while KYOTE is free. The Kentucky Council on Postsecondary Education also determined minimum placement scores on COMPASS and KYOTE as mandated by Unbridled Learning ("Guidelines for admission to the state-supported postsecondary education institutions in Kentucky," 2011) . If students meet the minimum competency score on any one of the examinations, then they are deemed "college ready" and can enroll in a college credit-bearing mathematics course.

Common Core State Standards Initiative

On February 10, 2010, Kentucky made history by being the first state to adopt the Common Core State Standards (CCSS). The CCSS were designed to be more rigorous, focused, and applicable (Holiday, 2010) than previous standards. They are aligned across grade levels and are specific with regard to what content is taught at a particular grade level. The high school mathematics standards for content are divided into seven domains: Algebra, Geometry, Modeling, Function, Number and Quantity, and Statistics and Probability. Within each domain are specific concepts and skills that all high school students should know and be able to do to be ready for college and productive careers ("Common core state standards inititative," 2011). All of the domains address specific content except Modeling, which describes more of the various strategies students should be able to implement to solve problems.

Research to Reflect Adoption of Common Core

During the 2012/2013 academic school year, a research study was conducted to determine if Kentucky universities' remedial course expectations reflect Common Core State Standards' breadth of knowledge, and using these expectations a comparison was made to Kentucky's regulated placement examinations: ACT, KYOTE, and COMPASS. In the research study, five of Kentucky public universities'

highest-level mathematics remediation course required before taking a mathematics credit-bearing course were analyzed using Common Core State Standards (CCSS). Each university's final examination test item was coded to match one or more CCSS item(s) using a coding matrix. This was completed to determine, what mathematical prerequisite knowledge do state universities consider necessary to be college ready? Specifically, what content domains do the state universities emphasize in their remediation courses? And does consistency across the state public universities exist with regard to the content domains? Data to help answer these questions was combined into one document referred to as Kentucky Mathematics College Readiness Expectations (KM-CRE). The study also analyzed ACT, COMPASS, and KYOTE examinations to determine the emphasis placed on each CCSS domain and to check consistency with KM-CRE.

A purposeful sample of university remedial course examinations was selected based on a number of factors. First, although minimal competency scores on placement examinations for remedial course placement are recommended for all postsecondary institutions, Unbridled Learning mandates only minimal requirements for public universities and community colleges ("Next generation learners," 2011). Second, public universities were selected only if their mathematics' faculty used comprehensive finals that were consistent across all sections in their highest non-credit bearing remedial course. Of the eight Kentucky public universities, five were selected for the study (two of the public colleges did not give a shared comprehensive final across sections, and one university did not offer remedial mathematics' courses). Community colleges were not included in this study because of the variety in programs and nature of the institutions and because those pursuing a bachelor's degree often transfer to a public university. Thus, the expectations of four-year public institutions are often the goals for the community colleges, as well.

Once the criteria were determined for inclusion in the study, the researcher reviewed each university's website to determine the highest remediation course prior to a credit-bearing course. The universities listed these classes as either Intermediate or Developmental Algebra. Course descriptions included topics such as exponents, integers, fractions, decimals, square roots, percent with applications, basic geometry, the real number system, algebraic expressions, linear and quadratic equations, inequalities, polynomials, graphing linear and quadratic functions, graphing circles, factoring, systems of equations, and radical expressions.

Faculty and instructors from the included universities submitted comprehensive final examinations for the highest non-credit-bearing mathematics course. Each final examination item was analyzed using a Common Core State Standards coding instrument. This instrument was a matrix of Common Core State Standards in Mathematics (CCSSM) from 5th grade through high school. The CCSSM for 6th grade through high school are divided into eight content categories: Ratios and Proportional Relationships; The Number System; Number and Quantity; Expressions and Equations; Algebra; Functions; Geometry; and Statistics and Probability. Under each of these content categories, lists of standards identify and describe specific content knowledge. Using a "hit" system, the conceptual category was first identified and then the standard(s) assessed on the course final examination was noted. Once the standard was identified, a "hit" was recorded on the CCSS coding instrument. For some questions, multiple "hits" were recorded if more than one

standard was assessed with no more than three standards recorded.

Data Analysis

The percent of emphasis on content was determined for each conceptual category. In order to determine the percent of emphasis on content, each conceptual category "hit" count was totaled and divided by the total number of "hits" recorded in the CCSS coding instrument for each university's final examination. For instance, in the category of Algebra, if 10 hits were recorded and a total of 30 hits were recorded in all categories on the CCSS coding instrument, then the percent of emphasis for that university's final examination on Algebra was 33.3% (10 out of 30).

Placement Examination Data Collection Procedures

The research and development department of ACT provided a released ACT mathematics examination. All sixty items on the mathematics portion were analyzed. The research and development department of COMPASS granted the researcher permission to take multiple online examinations to analyze different mathematic's content. Based on the design of COMPASS, both correct and incorrect answers on the examination were given to view a multitude of questions covering different content and difficulty levels. The examination was completed twice. The first examination was completed using the method of answering one question correctly followed by one incorrect answer. This strategy was used to represent a mid-range student. This method provided 15 questions and deemed the test taker ready for algebra. On the second examination, two questions were answered incorrectly and one question was answered correctly. This strategy intended to represent a struggling student. Using this method, 35 questions were given. Using these two examinations, 50 questions were analyzed, which was a similar number of question items than ACT. To analyze the KYOTE examination, Dr. Newman at Northern Kentucky University was contacted and permission was received for the researcher to become a test administrator in order to analyze test items. This allowed the researcher access to a 31-item test. Each question was analyzed for content.

Research Findings

Percent of Emphasis of CCSS Mathematics Content for 5 Public Universities: Using the "hit" sytem to determine the number of standards assessed in each CCSS content domain, the percent of emphasis was determined for each university (See Table 1). Consistency was operationally defined across universities as having 3 of the 5 universities with a range of 3% or less of emphasis. The highlighted cells represent those domains that met the criteria. Meanwhile, Figure 1 shows a comparison of all universities in a bar graph format.

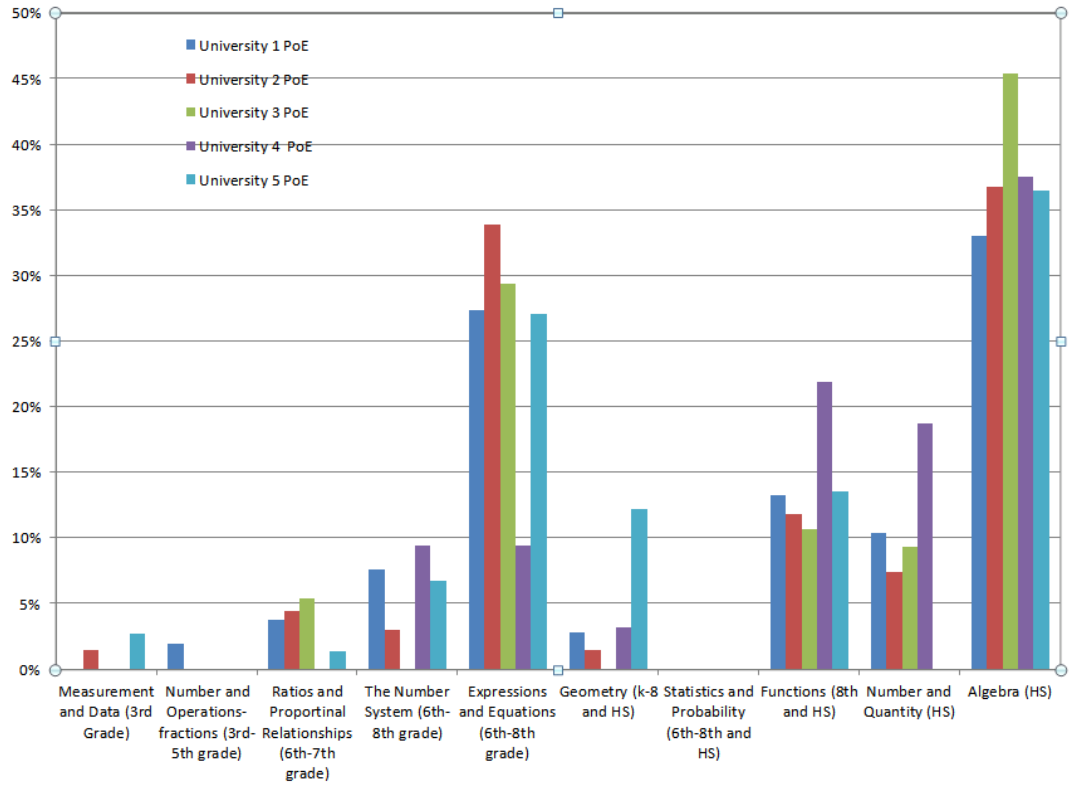
Consistently Emphasized: The two most consistently emphasized domains were Expressions and Equations and Algebra. No emphasis was placed on the domain of Statistics and Probability by any university. Less than 5% emphasis was placed on Ratios and Proportional Relationships across all universities. Geometry had a very low percent of emphasis across universities with University 5 serving as an outlier. It had a 12% combined percent of emphasis across the middle and high school domains.

Percent of Emphasis placed on Middle School Content Domains: This research study was intended to determine the mathematics content considered necessary for college readiness.

Table 1
Percent of Emphasis for Each University

Domain Category	University 1 Percent of Emphasis	University 2 Percent of Emphasis	University 3 Percent of Emphasis	University 4 Percent of Emphasis	University 5 Percent of Emphasis
Measurement and Data	0%	1%	0%	0%	3%
Number and Operations- fractions	2%	0%	0%	0%	0%
Ratios and Proportional Relationships	4%	4%	5%	0%	1%
The Number System	8%	3%	0%	9%	7%
Expressions and Equations	27%	34%	29%	9%	27%
Geometry	3%	1%	0%	3%	12%
Statistics and Probability	0%	0%	0%	0%	0%
Functions	13%	12%	11%	22%	14%
Number and Quantity	10%	7%	9%	19%	0%
Algebra	33%	37%	45%	38%	36%

Figure 1. Comparison of CCSS Domains for Each University Percent of Emphasis Chart



Surprisingly, a large percentage of the identified college readiness mathematics from universities across the state was from middle school-level CCSS domains (See Table 2). Universities 1 and 2 had a near 50% split between middle school and high school content domains. Universities 3 and 5 were close to a 40/60 split between middle and high school content. Meanwhile, university 4 had a 30/70 split. Considering that students are required to take four years of high school mathematics in Kentucky, the amount of emphasis placed on middle school mathematics is surprising and also disconcerting.

Table 2
Percent of Emphasis Table across Grade Bands

Domain Category	University 1 PoE	University 2 PoE	University 3 PoE	University 4 PoE	University 5 PoE	Average
Grade levels 6th-8th						
Ratios and Proportional Relationships (6th-7th grade)	4%	4%	5%	0%	1%	3%
The Number System (6th-8th grade)	8%	3%	0%	9%	7%	5%
Expressions and Equations (6th-8th grade)	27%	34%	29%	9%	27%	25%
Geometry (6-8)	1%	1%	0%	0%	1%	1%
Statistics and Probability (6th-8th)	0%	0%	0%	0%	0%	0%
Functions 8th	7%	4%	3%	9%	4%	5%
Total	47%	46%	37%	27%	40%	39%
High School Level						
Geometry HS	2%	0%	0%	3%	11%	3%
Functions HS	7%	7%	8%	13%	9%	9%
Number and Quantity (HS)	10%	7%	9%	19%	0%	9%
Algebra (HS)	33%	37%	45%	38%	36%	38%
Statistics HS	0%	0%	0%	0%	0%	0%
Total	52%	51%	62%	73%	56%	59%

Spending four years in a mathematics class should prepare students well beyond middle school mathematics content. With the adoption of the new Common Core State Standards, expectations for college and career readiness should increase. If the universities have aligned their remediation courses to Common Core State Standards as directed by legislation, then higher level mathematics content knowledge should be the expectation and should be reflected in remedial course finals.

Percent of Emphasis placed in the "Algebra" Domain: Another interesting finding in the analysis of percent of emphasis of content domains across universities is the amount of emphasis placed on Expressions and Equations, Functions, and Algebra. All of these combine to describe Algebra readiness.

Colleges, on average, have a 38% emphasis on Algebra, a 28% emphasis on Expressions and Equations, and 13% emphasis on Functions on their final examinations. This combines for 79% of emphasis placed on Algebra readiness. Based on these findings, Kentucky College Readiness Expectations identified on mathematics course finals would be better described as Kentucky Mathematics Algebra Readiness Expectations.

With the adoption and implementation of the Common Core State Standards in Kentucky's public schools, the holistic mathematics student's college readiness expectations should be increased. Students should be expected to display knowledge of all content domains including probability and statistics, and geometry. There should be an increased expectation of knowledge in high school standards instead of near equal expectations between middle and high school standards. The educational system from kindergarten to college must reflect the importance of higher-level mathematics for holistic nation-wide change to occur.

The Kentucky Mathematics College Readiness Expectations

Using the data collected from the five universities in the study, the Kentucky Mathematics College Readiness Expectations (KM-CRE) was developed. All CCSSM domains that received "hits" from at least three of the universities were included in the KM-CRE. All standards within the included domains were included in the KM-CRE document.

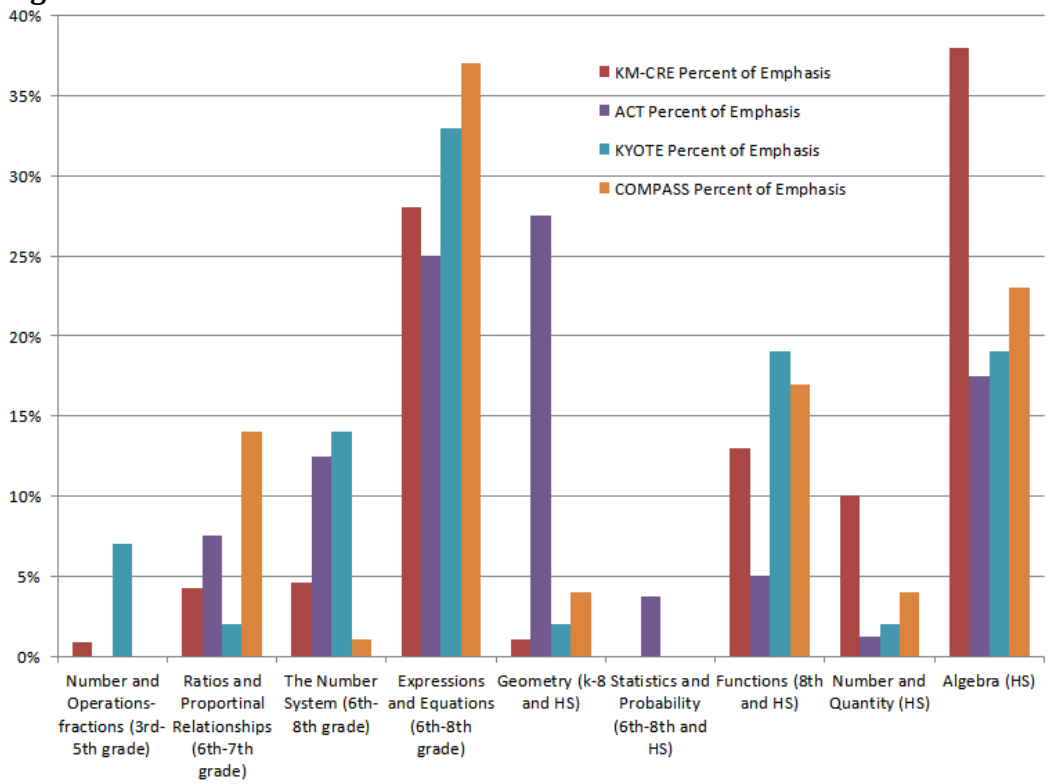
Analysis of Placement Examinations with Common Core State Standards

As a second component of this research study, an item analysis of a version of Kentucky's regulated placement examinations—KYOTE, ACT, and COMPASS—was conducted. Using the same process for item analysis as the remedial course finals, each test item was matched to one or more Common Core State Standards using the recording matrix. The percent of emphasis was determined for each placement examination. Additionally, the KM-CRE was compared to each placement examination to determine if there was consistency of emphasis placed on each CCSS domain (see Table 3 and Chart 2).

Table 3
Comparison of Percent of Emphasis (PoE) among Placement Examinations

CCSS Domain Category	KM-CRE PoE	ACT PoE	KYOTE PoE	COMPASS PoE
Number and Operations- fractions	1%	0%	7%	0%
Ratios and Proportional Relationships	4%	8%	2%	14%
The Number System	5%	13%	14%	1%
Expressions and Equations	28%	25%	33%	37%
Geometry	1%	28%	2%	4%
Statistics and Probability	0%	4%	0%	0%
Functions	13%	5%	19%	17%
Number and Quantity	10%	1%	2%	4%
Algebra	38%	18%	19%	23%
Total	100%	100%	100%	100%

Figure 2



From these side-by-side comparisons, it is easy to determine that colleges and universities place a higher emphasis on the Algebra domain than the Kentucky regulated placement examinations. ACT de-emphasizes Expressions and Equations, and Functions while dramatically emphasizing Geometry compared to the other assessments with a rate of 24%. ACT is the only assessment with expectations for knowledge in Statistics and Probability and that is at a minimal rate of 4%. Falling in line with the universities' percent of emphasis on Algebra readiness (79%), COMPASS and KYOTE place a combined emphasis on Expressions and Equations, Functions, and Algebra at 77% and 72%, respectively. This is an extremely high value being placed on Algebra above the other mathematical domains established by CCSS to be college and career ready. ACT better balances their emphasis with only a 55% emphasis placed on Algebra readiness.

Percent of Emphasis placed in the "Data and Measurement" Domain: The amount of emphasis placed on Statistics and Probability, and Geometry by college readiness examinations is surprising. ACT is the only examination in the study that assesses Statistics and Probability; however, it is only a small percent of emphasis of 3%. Likewise, Geometry is virtually ignored by all college readiness examinations except ACT. KYOTE (2%) and COMPASS (4%) only assess Geometry at a little higher rate than the universities (1%). In a data-driven world, it is surprising to see such little emphasis placed on Data and Measurement. These domains easily reason to be the most applicable to the real world, yet have the smallest amount of percent of emphasis on most college readiness assessments. Even more surprising is the fact that the cut scores established by placement examinations or successful completion of the college remediation course at the included universities allows a student to enroll in an Introduction to Statistics course. With no statistics assessment items on an examination, a student cannot be appropriately deemed college ready for a statistics course; yet the universities are allowing student enrollment.

Implications on Future Assessments

Roach, Niebling, and Kurz (2008) stated that educational testing systems are federally mandated to have standards-based alignment; yet few research studies have been conducted to ensure that such alignments occur. Students in Kentucky are required to take placement examinations to determine if they are college ready; yet this research indicates that Kentucky's testing system is not in alignment with college readiness expectations as defined by Common Core State Standards for Mathematics. Test developers in Kentucky should take into consideration what state colleges expect students taking mathematics to know and be able to do when entering college. These expectations are apparent through their performance on remediation course finals. The KM-CRE data should be considered when developing assessments that deem high school graduates college-ready. As Brown and Conley (2007) suggest, "If states do wish to employ their high school exams to generate information on college readiness or placement, they will likely need to revisit the content domains from which examination items are drawn, the number and difficulty of test items, and the format used for testing" (pg. 153). Their point is supported by research data from this study. Holistic coverage of CCSS did not occur in both the KM-CRE and Kentucky placement examinations. Revision of assessments to include domains, clusters, and standards that Kentucky education systems value should be made to improve

alignment between expectations and assessments.

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