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Common Core Math and Critical Reasoning

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Title Page

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Signature Sheet

This thesis, written under the direction of the candidate's thesis advisor and approved by the Chair of the Master's program, has been presented to and accepted by the Faculty of Education in partial fulfillment of the requirements for the degree of Master of Science. The content and research methodologies presented in this work represent the work of the candidate alone.

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Abstract

This teacher research action study compared the performance of students in mathematical critical reasoning for selected strands of math under the new Common Core Math Standards with their performance under the old California State Standards. Student scores from in-class tests and quizzes were comparatively analyzed over the duration of a year in one sixth grade classroom in Northern California. Findings from this study indicated a minimal increase in the critical reasoning skills of the students under the Common Core Standards when compared to the California State Standards. The results of the study imply that there is a need for longitudinal research that measures mathematical critical reasoning that correlates with changes in the teaching standards.

Chapter 1 Introduction

Prior to adopting the Common Core Math Standards, I had dedicated considerable time to teaching algorithms with students for solving math problems. Students had reported that word problems were challenging under the old Content Math Standards, and there was little collaboration or teamwork required among the students in the class for learning mathematics. It was evident that once students arrived at an answer they simply identified it by circling the correct answer. The old California Math Standards seemingly did not require evidence justifying the process and method for solving a math problem. The Common Core Math Standards places significantly more emphasis on critical reasoning and collaboration among student peers.

If students only learn the information that is fed to them, they have not learned how to think for themselves, they have merely learned how to memorize facts. If they are taught to "think," their potential knowledge base is endless. Higher-order thinking, which is built from lower-order thinking, is more than memorizing facts: it involves multiple thinking processes. These processes include taking in the facts and making inferences, restating facts, and connecting these facts to others in order to manipulate them. All of this leads to the ability to find new solutions to new problems. As Bruner (1957) explains, "Reasoning refers to the process of drawing conclusions or inferences from information. Reasoning always requires going beyond the information that is given" (p. 97).

Common Core math includes multi-step problems and incorporates language tools that require students to chronicle the steps they take to get the answer and detail what strategies they used. This level of attention helps students gain and demonstrate sound foundational knowledge of the concepts, while using reasoning skills that are applicable across all curricula and outside the classroom.

This study attempted to inquire into whether the Common Core Mathematics Standards (CCMS) requires students to apply a higher level of reasoning than the previous California State mathematics standards (CSMS). General comments from the press coverage at large have stated that the CCMS are designed to focus on the how and why, and they reduce the number of mathematical domains a student must complete at grade level each year. For example, students are now required to provide written evidence on what formula they used to reach their solutions as a result of the CCMS. Further, another key element of the CCMS involves collaboration with one's peers to increase critical thinking and reasoning skills.

Statement of Purpose

The purpose of this study was to examine, evaluate, and compare in-class evidence generated from students' use of critical reasoning skills under the CCMS for 6th grade math with the now retired CSMS for sixth grade math. This study was focused on comparing student-generated evidence for two mathematical domains and their corresponding strands – namely 1) Number sense (Fractions, Decimals and Percent) and 2) Ratio and proportional relationships. Both domains and corresponding strands are identified in the CCMS and the CSMS respectively. Using the results of in-class administered student math test scores and direct observation of student in-class work, this study was designed to determine if there was an improvement in the critical reasoning skills of students due to the requirements of the CCMS in comparison to the CSMS.

Research Questions

What is the effect of the Common Core Math Standards on critical reasoning skills for students in a sixth grade mathematics classroom? Do the new math standards evoke and develop a higher

level of critical reasoning skills among students in comparison to the previous California State Math Standards?

Theoretical Rationale

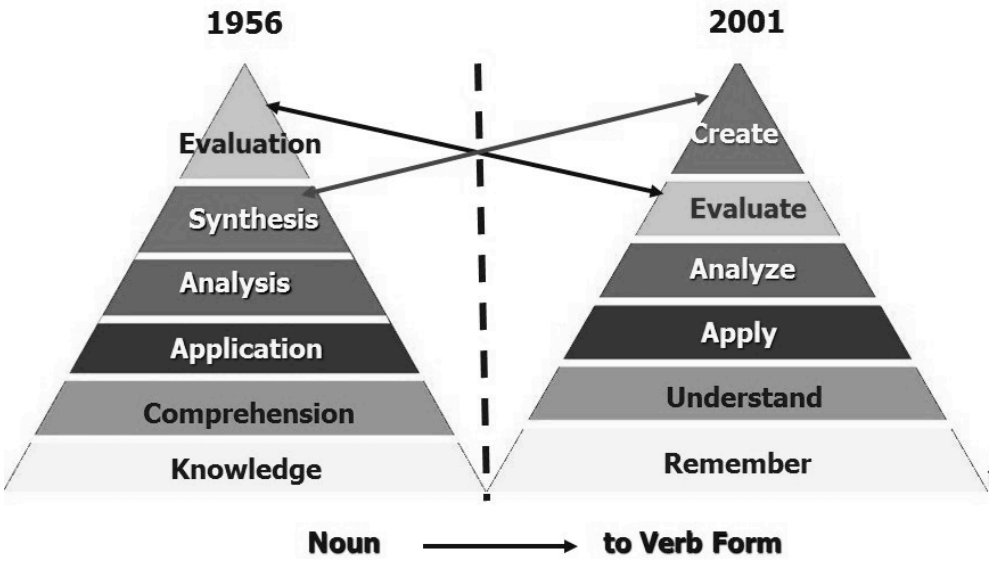
Many educational theorists, specialists, and researchers have addressed the processes of thinking and learning. John Dewey (1933) described thinking as "a progression of events. According to Dewey, this process moves from reflection to inquiry, then to the critical thought process that leads to a 'conclusion that can be substantiate'" (p. 5). "Thinking does not occur spontaneously but must be 'evoked" by "problems" and "questions" (p. 15). Dewey's research about problem-solving has produced a pedagogy of teaching students to develop awareness of their reasoning skills. Dewey's ideas match current dialogues and investigations about problem-solving, meta-cognitive approaches and the significance of teaching students to assess their thinking processes (Kauchak & Eggen, 1998).

However, the task of defining "thinking skills, reasoning, critical thought, and problem solving" has been referred to as a "conceptual swamp" in a study by Cuban (1984), cited in Lewis & Smith, (1993, p. 1), and as a "century old problem" for which "there is no well-established taxonomy or typology" (Haladyna, 1997, p. 32). "In addition, explanations of how learning occurs have been viewed as inadequate; with no single theory adequately explaining how all learning takes place" (Crowl, Kaminsky, & Podell, 1997, p. 23).

In 1956, Benjamin Bloom, along with other educational psychologists, classified and developed a taxonomy for learning. In 2009, Lorin Anderson, a student of Bloom and David Krathwohl, revised the taxonomy to be more relevant to the twenty-first century by moving from a static to a dynamic conception of the elements (see Table 1).

Table 1.

Comparison of Bloom and the revised taxonomy of Anderson & Krathwohl



The idea behind CCMS is to highlight real-world applicability and reasoning skills over repetition memorization, with the idea of readying students for college and jobs. Kuznia (2012) writes that, "in some respects, it is a kind of backlash against the culture of testing that has intensified over the past decade" (p.11). In math, developing the correct answer won't be good enough; students will be expected to comprehend the basic concepts. For example, "middle schoolers may consider the question, 'What is multiplication?' (Answer: repeated addition)". "High school students may ask, 'what does the word number mean?'" (Kuznia, 2012, p.11**).** Educational theorists enable educators to develop teaching and learning models that inform their approaches to educating students. Generally such theorists have also influenced the development of national and or state standards for use in public education.

Assumptions

This study assumed that student-generated evidence sourced from in-class math tests and scores are primary indicators of the critical reasoning skills of sixth grade students in a math

classroom. The study assumed that the two math domains selected are representative of the respective math standards as set by the CCMS and CSMS. This study also assumed that the pedagogical approaches used in the classroom were normative to the respective math standards and followed the established guidelines from the State of California, the school district, and the school site.

Background and Need

The currently retired California Math Content Standards (CMCS) were developed in 1997; these math standards were products of the third National Council of Teachers of Mathematics (NCTM). The focus of these standards was to teach students *content* to prepare them for post-secondary study or technical careers: "Proficiency in most of mathematics is not an innate characteristic; it is achieved through persistence, effort, and practice on the part of students and rigorous and effective instruction on the part of teachers" (Mathematics Framework for California Public Schools, 1997, p.1).

The previous math book, "California Math" (Houghton Mifflin), that conformed to the CSMS contained ten lesson units and twenty-seven chapters. The new math book written with the CCMS, "California Math, Your Common Core Edition" (McGraw-Hill), has five units with twelve chapters. A review of this new textbook revealed that there were fewer strands under each mathematical domain and a substantial increase in word problems.

The State of California initially began introducing CCMS in 2010, with the aim of having all public schools adopt them by the year 2015. Common Core Math Standards were developed after scholars researched different state standards and identified inconsistencies in what students were learning in the U.S. They found that too often students were graduating high school unprepared for college and careers. Sandy Boyd, chief operating officer of Achieve Inc., reported

that recent high school graduates were reporting that they left high school ill-equipped for the expectancies they encountered in college or in the work place (Achieve, 2015, para 2).

Summary

Teaching sixth grade math last year using the retired content math standards, I found my students struggling over the obligatory four-word problems provided at the end of every lesson and test. This year, I implemented the new CCMS curriculum as directed by my principal. We have been required to adopt Common Core math by 2015. From the very beginning, my students found that word problems formed the majority of the math curriculum (over 70%). As a teacher, I spent significant time teaching collaboration skills to the class before teaching content from the new textbook selected for use under the CCMS. I wondered whether my students would gain an understanding of algorithms, due to the considerable amount of time spent learning to solve word problems.

Chapter 2 Review of the Literature

Introduction

This review of the relevant literature envelopes the following areas of scholarship: 1) Historical Context for Math standards; 2) A comparison of the CCMS and the CSMS; and 3) Relevant scholarship on Mathematics and Critical Reasoning. The literature on "Historical Context" is further organized into a sub-section on the "Standards Movement."

Historical Context

In the late twentieth century, low levels of academic achievement among American students became a national issue. In 1975, the College Board pointed out the decline of SAT scores. In 1983, a report titled *A Nation at Risk,* prepared by the National Commission on Excellence in Education (NCEE) criticized the mediocrity and complacency of American education. It called for higher standards for teachers and students, a core curriculum for all students, higher standards for high school graduation and college entrance, a longer school day and year, and higher salaries for teachers. In 1989 and 1990, President George W. Bush set national goals for education using the NCEE recommendations. As Lee (2000) noted, "in sum, from the 1970s up to today, the goals of education have been excellence in education. The NCEE standards allow uniform high quality of education in the situation of diverse forms of education" (pg. 1).

Over the past quarter of a century, the performance of curriculum standards has increased significantly in United States public schools system. Since the early 1980s, academic state standards have existed to tackle relaxed, performance and competence in education. Still, the mutual perception of public schools today is that they are not accountable enough. National leaders have called for changes for decades, with each new president reconstructing the standards

and how students are tested. "The No Child Left Behind Act (NCLB) was passed in 2001, and this act 'brought sweeping changes' to education" (1999, p.1).

The Standards Movement

The National Council of Teachers of Mathematics (NCTM) published a set of standards for teaching mathematics in 1989. Former Colorado Governor Roy Romer, who headed the National Education Goals Panel, said these standards demonstrated what needed to be fixed in all subject areas (Barton, 2009, p. 5). President H. W. Bush set the education agenda when, in 1989, he assembled the nation's governors at an education summit in Charlottesville, Virginia. A set of national goals to be established by 2000 emerged from this conference, which began a new era of collaboration (Barton, 2009, p. 5).

Diane Ravitch was an assistant Secretary of Education in the administration of President George Herbert Walker Bush. According to Ravitch, the NCLB tended to judge schools, teachers, and students exclusively on test scores; this was a "label and punishment" method to teaching and student achievement, which lead to its downfall. With the breakdown of NCLB, the Common Core Standards have been in development since about 2008, via meetings composed of commissioners of education, governors, corporate chief executive officers and renowned experts in higher education. Ravitch (2010) has noted that the "NCLB law required schools to test every child in grades 3-8 every year" (p. 1) and that by 2014 this law said that "every child must be 'proficient' or schools would face escalating sanctions" (p. 2). As specified by this law, "the ultimate sanction for failure to raise test scores was firing the staff and closing school" (p.1.).

Ravitch (1995) agreed with the need for uniformity of math standards to be taught in the US schools and for them to be the equivalent as those in other countries: "Mathematics and

science in one modern country are not- and should not be- markedly different from mathematics and science taught in other modern countries" (p. 6).

In 1994, Congress approved the Goals 2000, Educate America Act, which specified capital allocations to schools to advance their academics. The same year President Clinton passed the Improving America's Schools Act; this too allocated more money to schools to reform their academic frameworks. Under the argument that individual states having their own standards were ineffective, and that there was a need for more accountability, each congress attempted to advance standards and construct them to be more accountable. Barton (2009) explains that "by the beginning of the 21st century, strong action was taken at the federal level. This came in the form of the No Child Left Behind (NCLB) Act, which specified what states had to do regarding raising student achievement and improving the quality of teaching" (pg. 3).

Achieve Inc., a progressive, private education company established in 1996 by governors and prominent businessmen facilitated the launch of the American Diploma Project. Achieve Inc. is an organization that is strongly committed to ensuring that all students graduate from high school "college and career ready, or, in other words fully prepared academically for all opportunities they choose to pursue" (Achieve, Inc. 2010, para 1). The American Diploma Project, (ADP) was designed to make college and career readiness a priority in all states wherever Achieve, Inc. launched the ADP.

As Stotsky (2014) states, "the Common Core K-12 standards were developed by three private organizations in Washington D.C.: the National Governors Association (NGA), the Council for Chief State School Officers (CCSSO), and Achieve Inc. – all funded by a fourth private organization the Bill and Melinda Gates Foundation" (p.1). Over forty-three states have embraced the Common Core State Standards. The notion behind them is to develop the best

performance from students by outlining the knowledge, concepts, and skills students should attain in every grade. The National Council of Teacher of Mathematics fully supports the new standards. As Usiskin (2007) has noted, "the entire mathematical sciences community, including the Mathematical Association of America and the American Mathematical Society, endorse the standards" (p.38).

McCullam, the lead writer of the Common Core Math Standards, stated that educators should use the new math practices to encourage math students to develop new skills with a view to becoming proficient. As he puts it, "The Standards for Mathematics Practice describes varieties of expertise that mathematics educators at all levels should seek to develop in their students. These practices rest on important processes and proficiencies with longstanding importance in mathematics education" (2014, p. 2).

The CCMS and the CSMS compared

The Common Core Mathematics State Standards require students in every state to grasp the concepts and the process of how one solves mathematical problems. The new Common Core Math Standards have two types of standards; eight Mathematical Practice Standards (MPS) that are the same at each grade level; and Mathematical Content Standards (MCS), which are designed around grade level. The MCS are structured around cognitive development. The Mathematical Practice Standards, (MPS) are based on reasoning and proofs. According to the CCMS, as specified by the "MPS3.1: Students build proofs by induction and proofs by contradiction. Students build arguments and critique others reasoning" (CCMS p.7)**.**

The MPS identifies skills that students hopefully develop from kindergarten through twelfth Grade (Table 2). Grade-appropriate practices are taught each year with the understanding that the students will expand and broaden their mathematical skills.

Table 2.

Common Core Math Practices

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

Table 3 below provides a useful comparison of the standards from the CMCS and the CCMS respectively for sixth grade mathematics.

Table 3.

Comparison Between CMS and CCMS

California Math Content Standards 6th grade	**Common Core Math Standards 6th grade**
Number sense	Number Systems
Algebra and Functions	Ratio and Proportional Relationship
Measurement and Geometry	Expressions and Equations
Statistics, Data Analysis, and Probability	Statistics and Probability

The CMCS focused on five domains for sixth grade:

- Number sense
- Algebra and Functions
- Measurement and Geometry
- Statistics, Data Analysis, and Probability.
- Mathematical Reasoning

These 1997 standards laid out guiding principles to help students and teachers with the new standards. Mathematical reasoning and abstract understanding are not isolated from content; they are essential to the mathematical fluency that students master at the more advance levels (Mathematics Framework for California Public Schools, 1997, p. 3).

According to the California Department of Education, in 1997 (Mathematics Framework for California Public Schools, 2005, p. 2), the goal in mathematics education is for students to:

- Develop fluency in basic computational skills.
- Develop an understanding of mathematical concepts.
- Become mathematical problem solvers who can recognize and solve routine problems readily and can find ways to reach a solution or goal where no routine path is apparent.
- Communicate precisely about quantities, logical relationships, and unknown values through the use of signs, symbols, models, graphs, and mathematical terms.
- Reason mathematically by gathering data, analyzing evidence, and building arguments to support or refute hypotheses.
- Make connections among mathematical ideas and between mathematics and other disciplines.

Table 4 below provides a side-by-side comparison between the approaches that the CSMS and the CCMS utilize.

Table 4

Side-by-Side Look at Approach to the Standards

Guiding Principles and Key Components CMCS	**Common Core Math Practices CCMS**
Develop fluency	Make sense of problems and persevere
Communicate Precisely	Reason abstractly and quantitatively
Develop logical thinking	Construct viable arguments
Make connections	Model with mathematics
Apply mathematics to everyday life	Use appropriate tools strategically
Develop an appreciation for the beauty and power of mathematics	Attend to precision
	Look for and make use of structure
	Look for and express regularity

Critical Reasoning in Mathematics

Katie Larson (2013) wrote a report on developing children's proportional reasoning titled '*Instructional Strategies That Go the Distance'*. She discusses the importance of middle grade school students being able to reason proportionally. Larson argues that "proportional reasoning is difficult to develop because it requires students to make significant shifts in thinking" (p. 42). The CCMS place significant emphasis on proportional relationships and the use of reasoning. According to Piaget, at this "concrete operational" stage of a child's development, children are developing logical thinking and reasoning, so it is the right time for this instruction to take place.

How well are schools and educational publishers responding to the challenge of helping students develop critical reasoning and higher level thinking? Quellmalz (1987), believes their performance leaves much to be desired: “Schools' commitment to higher order thinking has been largely rhetorical, while curriculum development has been infrequent and ineffective” (p. 86). In most classrooms higher order thinking gets little or no consideration. “When higher order questions do occur, they often concern specific, isolated skills; they seldom ask students to sustain a line of reasoning in order to draw a conclusion or explain a judgment" (p. 94). Quellmalz concludes his depressing evaluation by saying: "We have mountains of test data to document that most students of all ages do not perform well on higher order tasks" (p. 95).

“Educators must teach critical thinking because critical thinking is a skill which makes people fully human” (Pinkney &Shaughnessy, 2013, p.346). Justifying the steps in attaining an answer invokes critical thinking in all students. “Critical thinking is perceived as a cognitive capacity that allows one to convey meaning to disperse ideas, capacitating people to meaningful dialogue with others” (Brady, 2008,p. 65).

Aizikovitsh-Udi researched and wrote an article titled *‘Developing Critical Thinking Skills in Mathematics Education’*. She stated, “In the field of education, it is generally agreed upon that Critical Thinking capabilities are crucial to one’s success in the modern world” (Aizikovitsh-Uni, 2011, p.1).

Ennis (1989), describes Critical Thinking as “reasonable reflection focused on deciding what to believe or do” (p. 1). Ennis believed that critical thinking was a practical activity based on “Clarity, basis, inference, and action” (cited in Pinkney, & Shaughnessy, 2013, p. 350). Paradigms set forth by Bloom and Ennis suggest that educators must help students develop critical thinking skills, building on the skills learners have already to do this.

According to Boaler (2013), “the new Common Core Math curriculum gives more time for depth and exploration than the curricula it has replaced by removing some of the redundant methods students will never need or use”(para. 10). The Common Core Math standards therefore suggest that it will now encourage students to spend more time justifying their reasoning and understanding the steps taken to solve a mathematical problem.

“Most people think math is computation at the elementary level – drilling them in the skills”, said Jeanie Behrend, (2013), an education professor of math education at California State University, Fresno. Behrend further explains that “math is really about application and problem solving” (para. 4). This is a statement that has resonated time and time again with curriculum standard composers; critical thinking to problem solve is the approach sought with the new Common Core Math Standards. A major requirement in the Common Core is the need for students to discuss ideas and justify their thinking. “There is a good purpose for this; justification and reasoning are two of the acts that lie at the heart of mathematics” (Boaler, 2013). With Common Core math standards, the focus is on the high frequency thinking skills that students need to master. These skills teach children how to process, analyze, evaluate, produce, and present their ideas with rich content and relevant thinking.

Summary

The review of the literature revealed that there is an abundance of research that addresses the evolution of math standards over time and the arc of progress toward common math standards. Multiple studies have illustrated the need to include critical reasoning skills in math. However, there are few studies if any that offer concrete evidence that supports the idea that the CCMS increases critical reasoning skills. Since the implementation of the CCMS is still

underway, it may be that the research studies that inquire into the effects of the new math standards and critical reasoning skills are forthcoming.

Chapter 3 Method

Research Approach

This study utilizes a quantitative approach. It compares student performance data from two semesters—one from when the CSMS was in effect, and the second from after the adoption of the CCMS. This research project was designed to see if there were any improvements in students' reasoning skills when they were taught and studied with the CCMS. The researcher was involved in both instruction and assessment. Comparing scores from the two sets of standards revealed how students did on the tests when using the two different sets of standards to guide their learning.

Ethical Standards

This study adheres to the ethical standards for protection of human subjects of the American Psychological Association (2010). Additionally, a research proposal was submitted and reviewed by the Dominican University of California Institutional Review Board for the Protection of Human Subjects (IRBPHS), who approved this proposal (The IRBPHS assigned number is 10286).

Access and Permissions

The school administrator at the site granted written permission to the researcher for conducting this study. As a component of teacher action research, this study was conducted within the process of the daily class experiences for the students. Each student received a numeric code to protect any identifying information from being linked to test scores and related data.

Sample and Site

This study was conducted in one rural Northern California, public, elementary sixth-grade classroom. The school serves approximately 125 students, with one classroom per grade. All classrooms are self-contained, with the teacher teaching all subjects. The sample group for this study included eighteen sixth graders between the ages of ten to twelve years old.

Data Collection Strategies

Each student was given a number (one through eighteen) to provide anonymity throughout the data collection process. Test score data were collected from the administration of tests during the regular course of instruction with the appropriate lesson units. Both CMCS and CCMS chapter tests contained twenty multiple-choice questions, with a weight of five points for each question. A score of sixty percent was needed to pass the tests. The unit tests of CCMS and CMCS consisted of twenty-five questions; the CMCS had twenty-five multiple-choice questions, which included four word questions. The CCMS' five short essay questions required a rubric, which explicitly explains what steps a student must demonstrate in order to obtain a score, with the possibility of scoring zero to five points.

Data Analysis Approach

Test scores from both CCMS and CMCS were then compared and analyzed. The researcher compared a chapter test from each domain and from each set of standards. Each of the chapter tests contained the same amount of questions with multiple-choice responses and, all questions were weighted the same (five points each). The test scores were compared for similarities. The unit tests were approached in a different manner. The researcher examined the four word questions on the unit tests. Similarities and differences were identified and compared

in order to determine whether working under the CCMS lead students to an increase in critical reasoning skills as compared to the CMCS.

The researcher examined the results of the word problems to see if there were major discrepancies in the results. This was accomplished through a multi-pronged approach. First, the researcher looked at the scores and noted that there were similar scores between the two sets of standards. However, some discrepancies existed in the test answer requirements. The CCMS unit test had multiple-choice questions, which were weighed four points each and short answer questions that were weighted four points. A rubric was used to score the word questions. The student had the possibility to score zero to four. The CMCS unit test word problems were multiple-choice answers - they were weighted four points each. Data were analyzed by creating tables showing the test scores, including each student's mean score, overall mean score, and standard deviation between the two sets of standards.

Chapter 4 Findings

The purpose of this study was to determine if the CCMS had an effect on critical reasoning skills for students in a sixth-grade mathematics classroom compared to the skills of the students taught with the same domains using CMCS. Although there are limitations to this study, it provides an important contribution to the ongoing research on the impact of the CCMS on critical reasoning skills. It also adds to the literature suggesting that CCMS are more effective in helping students develop students' critical reasoning skills in mathematics that the previous standards. A comparative analysis of the results of student performance on chapter and unit tests was undertaken to examine the critical math reasoning skills of students as follows.

Test Results CMCS

Table 5

CMCS Chapter Test Scores on Fractions, Decimals, and Percent

Student	CMCS Chapter Test Fractions, Decimals, and Percent
1	88
2	88
3	76
4	68
5	76
6	100
	100
8	100
9	88
10	76
11	88

12	68
13	56
14	88
15	88
16	100
17	100
18	88
Mean	**85.33**

Table 5 displays the scores from the tests based on three chapters (fractions, decimals, and percentages) that were aggregated by student and a mean for each aggregated student score calculated respectively. The overall mean for the total class of students was 85.33.

Table 6 displays scores from the CMCS unit test on Fractions, Decimals, and Percentages. The overall mean was 76.11. Each question was a multiple-choice question, including the word problems.

Table 6.

CMCS Unit Test Fractions, Decimals, and Percent

Student	**CMCS Unit Test Fractions, Decimals, and Percent**
1	100
2	100
3	75
4	75
5	75
6	70
7	50
8	50
9	75
10	100
11	75
12	75

13	50
14	75
15	75
16	75
17	100
18	75
Mean	**76.11**

Table 7 displays the breakdown on four word questions in the CMCS unit test on Fractions, Decimal, and Percentages. Each question was multiple-choice and had a weight of four points.

Table 7.

Unit Test Word Problems on Fractions, Decimals and Percent

Unit Test on Fractions, decimals and Percent Word Problems CMCS					
Student	Q.1	Q.2	Q.3	Q.4	Mean
1	0	4	0	0	1
2	0	0	0	0	0
3	4	4	0	4	3
4	0	4	4	0	2
5	4	0	0	0	1
6	4	4	0	0	2
7	0	0	0	0	0
8	4	4	4	4	4
9	4	4	4	0	3
10	4	0	0	0	1
11	4	0	4	4	3
12	0	0	0	4	1
13	4	0	0	4	2
14	4	0	4	4	3
15	4	4	4	0	3
16	0	4	0	0	1
17	4	4	4	0	3
18	0	0	4	4	2
				Mean	**1.94**

Table 8 displays the scores of three chapters that were aggregated to find a mean for each student's' scores. The overall mean was 81.11.

Table 8.

CMCS Chapter Tests on Rates and Ratios

Student	CMCS Chapter tests on Rates and Ratios
1	100
2	100
3	76
4	76
5	72
6	72
7	64
8	56
9	100
10	100
11	92
12	76
13	64
14	80
15	76
16	76
17	100
18	80
Mean	**81.11**

Table 9 displays results from the CMCS unit test on Rates and Ratios. The test consisted of twenty-five questions. All questions were multiple- choice and all carried a weight of four points.

Table 9.

CMCS Unit Test on Rates and Ratios

Student	CMCS Unit Test Rates and Ratios
1	80
2	56

3	100
4	84
5	76
6	92
7	100
8	100
9	88
10	100
11	88
12	68
13	56
14	100
15	96
16	100
17	60
18	72
Mean	**84.22**

Table 10 displays results of the word problems from the CMCS unit test on Rates and Ratios. The questions were multiple-choice. A correct answer gave a score of four points.

Table 10.

CMCS Word Problems from Unit Test on Rates and Ratios

CMCS Unit Test on Rates and Ratios					
Student	Q.1	Q.2	Q.3	Q.4	Mean
1	4	0	0	0	1
2	0	4	0	0	1
3	4	0	4	4	3
4	4	4	4	0	3
5	4	0	0	0	1
6	4	4	0	0	2
7	0	0	0	0	0
8	0	4	4	4	3
9	4	4	4	0	3
10	4	0	0	0	1
11	0	0	0	0	0
12	0	0	0	4	1

13	4	0	0	4	2
14	4	0	4	4	3
15	4	4	4	0	3
16	0	4	0	0	1
17	0	4	0	0	1
18	4	4	4	4	4
				Mean	**1.83**

Tests Results CCMS

Table 11 displays the CCMS aggregated mean student scores from the four chapters. The overall mean for the class was 88.61.

Table 11.

CCMS Chapter Test on Fractions, Decimals, and Percent

Student	**CCMS Chapter Tests Fractions, Decimals, and Percent**
1	95
2	95
3	80
4	70
5	85
6	100
7	100
8	100
9	90
10	80
11	85
12	65
13	65
14	90
15	100
16	100
17	100
18	95
Mean	**88.61**

Table 12 displays the results of the CCMS unit tests. There were twenty-five questions. Five of the questions were short essay-style word problems. Twenty questions were multiple-choice, carrying a weight of four points. The word problems were scored on a rubric with the possibility of scoring zero to four points

Table 12.

CCMS Unit Tests on Fractions, Decimals, Percent

Student	**CCMS Unit Test Fractions, Decimals, and Percent**
1	89
2	89
3	78
4	67
5	78
6	100
7	99
8	100
9	89
10	78
11	89
12	67
13	56
14	89
15	86
16	100
17	100
18	89
Mean	**85.72**

Table 13 displays the scores from the unit test word problems on Decimals, Fractions, and Percent. A rubric was used to score, with the possibility of a grade from zero to four.

Table 13.

CCMS Word Problems scores on Unit test of Decimals, Fractions and Percent

CCMS Word Problems on Unit Test of Decimals, Fractions, and Percentages					
Student	Q.1	Q.2	Q.3	Q.4	**Mean**
1	4	3	3	4	3
2	2	4	4	3	3.25
3	4	1	4	3	3
4	3	4	4	2	3.25
5	2	1	4	3	2.5
6	3	3	2	2	2.5
7	4	4	4	3	3.75
8	0	3	2	2	1.75
9	4	4	4	4	4
10	3	3	2	3	2.75
11	4	4	3	3	3.5
12	4	4	4	4	4
13	3	2	4	4	3.25
14	3	2	1	1	1.75
15	4	3	3	3	3.25
16	1	3	1	2	1.75
17	4	4	3	3	3.5
18	3	2	2	2	2.25
				Mean	**2.94**

Table 14 displays the aggregated scores from three CCMS chapter tests; students were given a mean score. The overall mean from these tests was 83.61.

Table 14.

CCMS Chapter Tests on Rates and Ratios.

Student	**CCMS Chapter tests on Rates and Ratios**
1	100
2	100

3	95
4	75
5	70
6	85
7	65
8	55
9	100
10	100
11	90
12	75
13	65
14	80
15	75
16	95
17	100
18	80
Mean	**83.61**

Table 15 displays the CCMS results of the unit test on Rates and Ratios. The test was comprised of twenty-five questions. Twenty questions were multiple-choice and five questions were short essay word problems.

Table 15.

CCMS Unit Test on Rates and Ratio

Student	**CCMS Unit Test on Rates and Ratios**
1	100
2	100
3	97
4	73
5	76
6	85
7	98
8	65
9	100
10	100
11	90
12	75

13	65
14	100
15	75
16	95
17	100
18	80
Mean	**87.44**

Table 16 displays the scores from the unit test on Rates and Ratios word problems. A rubric was used with a possibility of scoring zero to four points.

Table 16.

CCMS Word Problems on Unit Test Rates and Ratios

CCMS Word Problems on Unit Test Rates and Ratios					
Student	Q.1	Q.2	Q.3	Q.4	Mean
1	2	1	3	4	2.2
2	2	4	4	3	3.25
3	4	1	4	3	3
4	3	4	3	2	3
5	2	1	4	3	2.5
6	2	3	2	4	2.75
7	3	4	4	3	3.5
8	1	3	2	2	2
9	4	4	4	4	4
10	3	3	2	3	2.75
11	3	4	4	3	3.5
12	4	4	4	4	4
13	3	2	4	4	3.25
14	3	2	1	2	2
15	4	3	3	3	3.25
16	1	3	2	2	2
17	3	3	3	3	3
18	4	2	3	2	2.75
				Mean	**2.93**

Table 17 displays the standard deviations compared between both sets of standards.

Table 17

Standard Deviation Between CMCS and CCMS Test Scores

CMCS Rates and Ratio Chapter Tests	CCMS Rates and Ratio Chapter Test	**Standard Deviation**
81.11	83.61	**1.76**
CMCS Rates and Ratio Unit	CCMS Rates and Ration Unit	
84.22	87.44	**2.78**
CMCS Decimals, Fractions, and Percent Chapter Tests	CCMS Decimals, Fractions, and Percent Chapter Tests	
85.33	88.61	**0.9**
CMCS Decimals, Fractions, and Percent Unit Test	CCMS Decimals, Fractions, and Percent Unit Test	
76.11	85.72	**6.8**

The comparison suggests that there was little deviation between both sets of standards. The notable difference was between the unit tests on Decimals, Fractions, and Percent, which showed a standard deviation of 6.8.

Table 18 displays the findings from the word problem scores when compared between the CSMS and the CCMS. The researcher examined the unit word problems and took note of the wording of the questions. The researcher found that the CSMS word questions were similar to the CCMS. However, there was a marked difference in how the students answered the questions. CSMS questions were multiple-choice and CCMS was composed of short essay type answers.

The students under the CSMS had very little explanations to get the answers, the word problems were multiple-choice, and no justification was required. Students studying under the CCMS were required to follow in a logical sequence; they were required to explain their reasoning and what step-by-step approach they used in solving the problem.

Table 18.

Comparison of Word Problem Mean Scores

CMCS Unit Test Word Problems Decimals, Fractions, and Percent.	CCMS Unit Test Word Problems Decimals, Fractions, and Percent.	Standard Deviation
1.94	2.94	**0.70**
CMCS Unit Test Word Problems on Rates and Ratio	CCMS Unit Test Word Problems on Rates and Ratio	
1.83	2.93	**0.78**

The word questions from the unit tests on Decimals, Fractions, and Percent showed a standard deviation of 0.70. The average score was 1.9 from the CMCS. CMCS provided multiple-choice options for the answers, and they were either right or wrong. The CCMS students had a higher mean score of 2.9. This was because there was a process in which they had to write out and justify their reasoning. With the CCMS, the student has a rubric, so students had an opportunity to get a partial score even if they arrived at the wrong answer.

The unit tests word problems from Rates and Ratios showed a standard deviation of 0.78. CMSC showed a mean score of 1.83, while the CCMS mean scores were slightly higher at 2.93. The tests were scored the same as the other unit tests, which allowed students from the CCMS to attain partial credit.

Summary of Major Findings

The findings from this study indicate that the CCMS are designed in such a way as to encourage students to develop their reasoning skills. The chapter tests were similar—each had the same amount of questions and multiple-choice answers. The unit tests, and in particular the word problems, posed major differences. The researcher found that there was a slight difference in scores on the *word problems,* with the CCMS scoring slightly higher. The CCMS questions are presented differently from the CMCS. The CCMS had no multiple-choice option available to help suggest an answer and thus required the student to rationalize the steps they took to solve a problem. This information led the researcher to believe that the CCMS, in fact, encouraged students to engage in a greater amount of critical reasoning in generating their answers. The CCMS presented math differently: for the actual tests, there were fewer direct computation questions, less multiple-choice answers, and more word problems. The CCMS emphasized word problems and placed a demand on students to explain their reasoning.

The tests found a slight increase in scores, but these results are not significant enough to reliably state that the CCMS improved student-reasoning skills. However, the examined scores from the unit test word problems did, in fact, show that the CCMS participants were encouraged to engage in critical reasoning more than the CMCS participants were.

The CCMS replaced the CMCS with an emphasis on reducing the number of domains being taught. The hope was that the use of the CCMS would increase students' critical reasoning skills. This study provided support for evidence of the reduced domains and analyzed data that demonstrated the use of reasoning. A change in pedagogical approach was required in actively implementing the CCMS and its goals and objectives. The intent of the CCMS's design to improve critical reasoning was noticeable through the researcher's observations; however, the

data did not provide significant evidence of the CCMS effect on students' critical reasoning skills.

Chapter 5 Discussion /Analysis

Comparison of Findings to the Literature

This study found that students demonstrated an increase in critical reasoning with the CCMS compared to students who studied under the CMCS. Studies have demonstrated the importance of critical reasoning, and the CCMS emphasizes student development of their critical reasoning skills: "Reasoning refers to the process of drawing conclusions or inferences from information. Reasoning always requires going beyond the information that is given" (Bruner, 1957).

Prior to the CCMS most pedagogy was content-based built on broad knowledge. However, studies around the CCMS have shown that critical reasoning pedagogy is moving away from this paradigm and introducing a new pedagogy to teach students to reason in a critical way. In spite of the challenges faced by schools that are moving to a critical thinking curriculum, there is the issue of reeducating the teachers to change their familiar pedagogy. " New pedagogy is needed, one that is focused on teaching students how to think critically rather than teaching course-content" (Flores, Matkin, et al., 2012). The U.S. educational standards are continuously being scrutinized and revised to ready our students for the future. As studies continue to evolve, no doubt standards will too.

Limitations/Gaps in the Research

First, the study only looked at results from two math domains – *Fractions, Decimals, and Percent* and *Rates* and *Ratios* from both the CMCS and CCMS.

Normally, there are three to four more domains to be covered, which may leave gaps in students' learning as they will not have comprehensively covered all the curriculum. This may prevent them from doing well on the tests they are given. Secondly, the study analyzed eighteen students from two different years, one using CMCS and the other using CCMS. A larger sample size or a long-term study, over multiple years, would help to strengthen the findings of this study. One major limitation is related to the pedagogical approaches used; they were not measured for effectiveness or likeness to the CMCS. Other limitations include the size of the sample group and comparisons of scores from a limited number of tests.

Implications for Future Research

Implications for future research suggest that more information is needed regarding the pedagogical changes necessary to implement the CCMS. This information would provide valuable data for researchers and developers of the CCMS, with a premise to the development of critical reasoning. Also, more research needs to be conducted around CCMS and the effects on critical reasoning among students. The CCMS are slowly being implemented; more time is needed to establish whether they do, in fact, improve students' critical reasoning skills.

Overall Significance of the Study

The study showed that students who studied under the CCMS did indeed improve their critical reasoning skills. Research has proven that math should be more than just rote learning. Students should reason, collaborate, and justify their thinking to find answers; as Boaler (2013) suggests, "justification and reasoning are two of the acts that lie at the heart of mathematics" (para 10). Mathematics should go beyond rote and computation problems and students need to learn to think critically and develop skills to understand, evaluate, and create solutions. This kind of thinking process will help ensure they become career and college ready. The rationale behind revising the standards was to ready our students for the workforce and college. The abilities to collaborate, critically analyze, and work in a team are key to succeeding in the modern workplace. This study provided promising results demonstrating that the CCMS has achieved the goal of improving students' critical reasoning skills, particularly in the design of their word problems and the associated pedagogical approach a teacher should take.

About the Author

Lorna Hayman is a sixth-grade teacher in a small rural school in Northern California. This year her school adopted the CCMS, and she was very interested in seeing if the new math curriculum would bring about any differences in critical reasoning among the students. She received her multi-subject credential from Dominican University in 2003 and is now furthering her education by earning a Master Degree in Education at Dominican. Currently, she lives in Northern California with her husband and two sons.

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