A Quality Math Curriculum in Support of Effective Teaching for Elementary Schools

William Hook, Wayne Bishop and John Hook
(Author's Version)
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Abstract: This paper presents a curriculum, textbook and test result analysis for the new (to California) elementary school "Key Standard" mathematics curriculum, transplanted in 1998 from it's foreign roots in Asia and Europe, locations with far different cultural and economic backgrounds. Based on topic analysis methods developed by Michigan State University, this curriculum is a "quality" curriculum, since it is closely aligned with the curriculum of the six leading TIMSS math countries. Five-year test results are presented for two cohorts totaling over 13,000 students, all from four "early adoption" urban districts where 68% of the students were economically disadvantaged. Included are two cohorts of English learning immigrants totaling over 4,400 students. Performance was found to be statistically superior to similar (control) districts which continued with the old 1991 curriculum and textbooks ($0.003 < p < 0.015$). The focus of this paper is on the transition from far-below to above average learning performance of these students over the 1998-2002 period.

1.0 INTRODUCTION

The Third International Math & Science Study (TIMSS) of 1995 found the six leading math countries were Singapore, Korea, Japan, Hong Kong, Belgium and the Czech Republic. U.S. students were significantly worse at the 56th percentile for 4th graders[1], the 32nd percentile for 8th graders[1], and the 12th percentile for 12 graders[2]. The 1995 TIMSS also included the acquisition of a very large amount of data relating to what students were actually taught, teaching methods, demographics, and other classroom data which might affect test results. The students tested represented a cross section of all the public school students in each country, and the reported test results were based on the mean score of all these tested students.

The National Research Center-TIMSS at Michigan State University carried out an extensive study to determine why the K-8th grade U.S. students lagged behind. This study found the six leading math countries had remarkably similar curricular content. The 21 participating U.S. states also had similar content to each other, and the differences between these two consensus curricula substantially explained the differences in test scores (Schmidt et al., 2002, abbreviated [S] for the balance of this paper). Four content characteristics were found to be important and were evaluated for each group:

- The number of topics for each grade (U.S. states had far too many topics, particularly in the lower grades; what the authors call "not focused")
- The degree of repetition of topics (U.S. curriculum was highly repetitive; topics were introduced too early, taught with too little depth, and were endlessly repeated)
- Logical order of topics (topics in U.S. were not presented in a logical, step-by-step order, termed by the authors as "not coherent")
- Level of topics (topics were not very demanding, especially in middle school years)

The consensus curriculum of the six leading nations was labeled a "quality" curriculum, and the less successful consensus curriculum of the U.S. states was labeled "inadequate".

The clear implication is that if a poor performing school, state or country would switch to a quality curriculum, performance would improve. Yet no experimental data was provided to support that implication, and in fact [S] as well as Leung (2005) warn about the cultural difficulty of importing practices into another nation. Further, no data was presented to show how hard-to-teach students, such as economically disadvantaged or immigrant students, would respond to a quality curriculum.

The original research described in this paper provides data on the above undocumented issues, and focuses on the introduction of a quality curriculum into four low-performing jurisdictions, as well as one high performing one. There are four principal aspects of our research:

(a) Performance Improvement Rate Results: The basis for our research is the time-history improvement of performance for an entity which decides to adopt a quality curriculum. This is the largest and most important difference between our paper and [S], since that paper only analyzes the results from one year and for only the 4th and 8th grades. Our research provides performance data for every grade from the 2nd to the 6th, and for every year during the 5 year period from 1998 to 2002. Thus the performance trend data is more accurate than is available from the TIMSS tests.

(b) Difficulty of Transplanting a Quality Curriculum to Another Culture: [S] actively discourages taking this step for most countries with the following cautionary warning (page16) ". .the practices of other nations can rarely by imported whole-cloth. Institutions and cultures differ too much". Our research, using experimental data, clearly demonstrates that a quality Asian/European curriculum can be successfully transplanted virtually intact to North America and gives superior results almost immediately. This is true even in school districts where parental involvement is almost certainly well below that of the typical Asian country.

(c) Economically Disadvantaged Students: Our research uses a statistical analysis of four poor-performing urban school districts with high percentages of economically disadvantaged students. It experimentally demonstrates that the introduction of a quality curriculum produces superior performance improvement rates for school districts having high percentages of such students when compared to similar districts utilizing an inadequate curriculum.

(d) Immigrant Students: [S] offers no data to demonstrate that immigrant students who are just learning the language of their new country can benefit by the use of a quality curriculum. Our research shows that this subclass of students, labeled "English Learners" in California, also produces superior performance improvement.

None of this is to take away from the powerful and well-researched [S] paper. Rather, our paper is the next logical step in the process started by [S], where we investigate important and specific time-dependent research topics or characteristics not covered by the [S] paper. This research is relevant to any entity which wishes to change to a quality curriculum in order to improve learning.

Data, methodology and analysis is presented on cohorts of California elementary school students from six urban school districts which had high percentages of economically disadvantaged and immigrant students. All employed the California "inadequate" 1991 curriculum through the school year ending in 1998, then four switched to a new "quality" curriculum. Two remained with the old curriculum and became the statistical "control" districts for the analysis. Data is also presented for one high-income suburban district which switched.

2. DATA TYPES AND SOURCES

2.1. *Test data*

All test result, sample size and demographic data was obtained from the California Department of Education STAR web site[3]. Test results are available for each grade from 2nd through 11th of each school and each school district in the state, and further categorized by demographics. In 1998 and 1999 test scores for "all students" and for "English learning" students were published. Additional demographic data was added starting in 2000. The same test series was used for the 5 year period 1998-2002, thus providing excellent continuity, and allowing the evaluation of meaningful cohorts of 2nd to 6th grade students.

The test used was the Stanford Achievement Test Series, Ninth Edition (SAT-9). It is a nationally normed, standardized test published by Harcourt, and features both math and problem-solving questions. The SAT-9 tests are a national test not tailored to any particular curriculum, and are designed to evaluate a cross section of math skills [4]. The test results are in the form of an average national percentile ranking, where the national average is, of course, the 50th percentile. Three sample 5th grade questions are given below[5]:

> **(1) Which fractions are not equal?** 2/7 and 8/28, 5/9 and 10/18, 7/11 and 14/22, 14/27 and 2/3, none of the above;
> **(2) Dan's test scores are 86, 87, 88, and 91. What grade must he get on the last test to get a 90 average for the term?** 98, 93, 92, 91, none of the above
> **(3) Solve (4/7)*x* = 28:** $x = 16$, $x = 28$, $x = 35$, $x = 48$, none of the above

2.2 *Curricular data, elementary school*

The "quality" composite 1995 curriculum of the six leading math countries is found in [S, figure 1] in the form of a grades 1-8 topics map, and in supporting text description. The "inadequate" composite 1995 curriculum of 21 U.S. states is also in [S, figure 2] and in the same format. The California elementary curriculum adopted in 1991 (CC91)[6] is in the form of a single set of standards for grades K-4, and a second set for grades 5-8, all in alignment with the National Council of Teachers of Mathematics 1989 Standards. The initial stage in reforming the CC91 curriculum was adopted in December 1997 (CC97)[7]. The final version of the reform curricula was adopted in December1998 [CC98][8], and is in the form of a set of Key Standards and a set of non-Key Standards for each grade K-7, where the complete set is identical to CC97.

2.3. *Textbook Content Data*

Since the expression of the new CC98 curriculum was in the textbooks actually used in the classroom, the state established a Content Review Panel (CRP) as the representatives of the academic mathematicians who researched and wrote the CC98. This panel is composed of professional PhD mathematicians, and is assumed to have the knowledge and background to thoroughly understand the California Key Standards curriculum, its history and context. Only when a textbook series has been deemed acceptable by the CRP is it sent to representatives of the education community for classroom considerations and final "adoption".

In the case of Saxon Math, the 4th, 5th and 6th grade Saxon textbooks did not meet the California standards at their indicated grade levels, but were a suitable match for a grade lower. Thus the Saxon 7th grade text was submitted and adopted for use in the California 6th grade, the Saxon 6th grade book for the 5th grade, and the Saxon 5th grade text for the 4th grade. The first 3 grades were acceptable as written, but with the 3rd grade option to use the 4th grade textbook. This more demanding textbook sequence was adopted in June, 1999. A complete set of grade 1-6 Saxon Math textbooks was obtained for this study, using the current California adopted ISBN numbers[9,10]. The 5th and 6th grade books are the same editions used by the four "early adoption" school districts. The 1st-4th grade books are slightly revised versions of the 1999 adoption books, but with the same lesson sets and content.

The two control districts used in our statistical study are Los Angeles Unified School District (LAUSD) and San Diego City School District (San Diego). Both refused to adopt the CC98 curricula, and continued to use the old CC91 curriculum and matching textbooks. Quest 2000[11]and MathLand[12] were the textbooks most used in the LAUSD (Klein, 2003). Quest 2000[11] and AnyTime Math[13] (for the first 3 grades) were primarily used in San Diego[14,15]. None of these textbook series were approved by the California Content Review Panel for use with the new CC98 curriculum. Copies of these old textbooks were also obtained for this study.

2.4. Saxon *Math transition data*

Four of the early adoption districts had very high percentages of economically disadvantaged students and English learning immigrant students, and very poor performance on the baseline SAT-9 test conducted in the spring of 1998. Data on the transition from the old CC91 curriculum and textbooks to the full use of the Saxon textbooks was obtained by contacting the curriculum department for each of the four districts, and obtaining this information via personal contact with either the director or designee[16]. In addition, the Northern California Saxon representative[17] had been in place during the entire SAT-9 period, and provided valuable historical data for the Sacramento district.

3. CONCEPTUAL FRAMEWORK

3.1. *The Quality Curriculum*

Our research was conceived with the primary goal of tying together two significant math education events which occurred during the period 1995 –2002, and providing statistical verification for the second event. The first event was the 1995 TIMSS and the resulting publication in 2002 of research by Michigan State University (MSU) on the subject of a "quality" curriculum [S]. The second event was the adoption in late 1998 of an Asian/European curriculum by California (CC98) and the subsequent appearance of articles in the newspapers describing the "stunning" performance improvement by a set of California school districts (Bishop, 2002).

The MSU TIMSS researchers concluded it was the *content* of the curricula of the six leading math countries which was primarily responsible for their superior performance, and called their composite curriculum a "quality" curriculum. One specific purpose of our research was to determine if the CC98 was also a quality curriculum. The

four elements of a quality curriculum were described in the introduction. We define a quality curriculum as having the following properties:

Number of topics "T" for each grade: For grades 1-3, **T ° N +1**, and for grades 4-6, **T ° 1.2N** , where N is the total number of topics for each grade from the composite curriculum of the six leading (A+) countries, as shown in Figure 1 of [S]. For example, N = 5 for the 1st grade, and so the total number of topics for the 1st grade must not exceed 6.

Degree of Repetition "R" of topics (the number of years a student returns to a topic during grades 1 through 7): **R ° 1.1P** where P = 71, the degree of repetition for the composite curriculum of the six leading countries (Table 1)

Logical order of topics or "coherence" (topics presented in a logical, step-by-step order): A curriculum is coherent if the total number of topics in the 1st grade $\mathbf{T°_1 ° 6,}$ **AND** if (using the definition in [S], page 9) "topics are articulated over time as a sequence of topics and performances that are logical and reflect, where appropriate, the sequential or hierarchical nature of the disciplinary content from which the subject matter derives", and including the explanatory material which follows the quote.

Level of demand of topics in the middle grades: Since virtually all curricula claim to have demanding topics in the middle grades, the topics map cannot be used to evaluate this factor. Instead a core group of six related 6th grade topics have been selected for textbook evaluation, all critical to the understanding of 8th grade algebra and all related to proportion, ratio and rate. These six topics have been highlighted in the 6th grade column of Table 2, starting with "decimal fractions" and ending with "proportionality problems". In order to qualify as a demanding curricula in the middle grades, the textbook adopted to match the candidate curriculum must demonstrate a strong emphasis on these six topics in the 6th grade. In evaluating a textbook, algebra which supports these topics is also included. Note that with the California Content Review Panel (CRP) system for textbook review, several professional mathematicians who are members of the CRP will have previously evaluated this property.

Table 1 - Total Number of Topics for Each Grade & Degree of Repetition

	Grade							Repetition
Curricula	1st	2nd	3rd	4th	5th	6th	7th	(R)[a]
A+ Countries Composite [S]	5	9	12	16	21	20	22	71
U.S. States Composite [S]	22	23	25	26	28	30	29	132
California 1991 (CC91)[b]	19	19	19	19	25	25	25	126
California 1997 (CC97)	10	12	15	20	22	18	18	82
California 1998 (CC98-Basic)	3	10	12	13	21	18	18	62

a. Number of years a student returns to a topic during the first 7 years.
b. Recommended topics for a band of grades, as per [S] endnote #6, p 16.

Table 2 –General Topic Trace Mapping (GTTM) using the NCREL website procedure for the CC98 curriculum

Topic / Grade	1	2	3	4	5	6	7
Whole Number Meaning	**2**	**2**	**2**	**2**	**2**		
Whole Number Operations	**2**	**2**	**2**	**2**	**2**	**2**	
Measurement and Units	**1**	**2**	**2**	**1**	**2**		**2**
Common Fractions		**2**	**2**	**2**	**2**	**2**	
Equations and Formulas	**1**	**1**	**2**	**2**	**2**	**2***	**2**
Data Representation & Analysis (Graphing)	**1**	**2**	**2**	**1**	**2**	**2**	**2**
2-D Geometry: Basics	**1**		**2**	**1**	**2**	**2**	**2**
Polygons & Circles	**1**	**2**	**2**	**1**	**2**	**2**	
Perimeter, Area & Volume	**1**		**2**	**1**	**2**	**2**	
Rounding & Significant Figures				**2**			
Estimating Computations (incl. mental math)		**1**	**2**	**2**	**2**	**2**	
Properties of Whole Number Operations		**2**		**2**	**2**	**2**	
Decimal Fractions		**2**	**2**	**2**	**2**	**2***	
Relationship of Common & Decimal Fractions			**1**	**2**	**2**	**2***	
Properties of Common & Decimal Fractions					**2**	**2***	**2**
Percentages					**2**	**2***	**2**
Proportionality Concepts						**2***	**2**
Proportionality Problems						**2***	**2**
2-D Coordinate Geometry				**2**	**2**		**2**
Negative Numbers, Integers & Their Properties				**2**	**2**	**2**	
Number Theory (primes & factorization)				**2**	**2**		**2**
Exponents, Roots & Radicals					**2**		**2**
Exponents & Orders of Magnitude						**2**	
Constructions w/ Straightedge & Compass					**2**		
3-D Geometry	**1**	**2**	**1**	**1**	**2**		**2**
Congruence & Similarity							**2**
Rational Numbers & Their Properties							**2**
Patterns, Relations & Functions	**2**	**2**	**2**	**2**			**2**
Slope & Trigonometry							**2**
Uncertainty & Probability			**1**	**1**	**1**	**2**	**2**
Real Numbers							**2**
Topics "Emphasized" (2's) = CC98-Basic	**3**	**10**	**12**	**13**	**21**	**18**	**18**
Topics "Taught" (1's) = CC98-Other	**7**	**2**	**3**	**7**	**1**	**0**	**0**
Total Topics (2's + 1's) = CC97	**10**	**12**	**15**	**20**	**22**	**18**	**18**

***Topics used to evaluate textbooks for "level of demand in the middle grades"**

3.2. *The California Curricula*

A Mathematics Framework document specifies the "intended content"[S] of a California curriculum through the use of a set of "standards", as well as supporting material which provides elaboration and considerations for the application of the standards. The CC98 version contains a set of standards researched and written by Stanford University mathematics professors, aligned with the international curricula of Singapore, Japan and Poland, and labeled the Key Standards. The primary focus of the Key Standards curriculum is to prepare all students for 8th grade Algebra I. CC98 also contains many

additional standards derived from the old 1991 adoption (CC91), which in turn was derived from the National Council of Teachers of Math 1989 Standards.

The Key Standards curriculum contains a sharply reduced number of topics in the early grades. For example, 1st grade Key Standards has only three topics, including Whole Number Meaning, Whole Number Operations, and Patterns, whereas the CC91 has 19 topics. Even the initial reform curriculum CC97 has 10 topics in the 1st grade (Table 2). In effect, the CC98 is really two curricula (i) the Key Standards core or basic curriculum, designated CC98-Basic in this paper, and (ii) the non-key standards, designated CC98-Other. Included in the CC98 Framework document is Chapter 2 (Math Content Standards) which gives all the standards. Chapter 3 (Grade-Level Considerations) describes how to implement the standards, using such terms as "area of emphasis", "particularly important", and "essential" for various "Key Standards". It is only the Key Standards which are described in Chapter 3; the non-key standards are not included, indicating they were less important. Chapter 4 (Instructional Strategies) includes the following recommendation for students who are falling behind their classmates: "focus on the more important standards, as noted in Chapter 3". A reasonable conclusion is that the authors recommend the Key Standards as a core curriculum for students who may fall behind for such reasons as lack of sophisticated parents or other home support issues, economic issues, language issues, or simple lack of math aptitude. The "other standards" provide topics for the brighter or more advantaged students. Another reason to focus on the Key Standards for all students is that a minimum of 70% of the questions on the California Standards Test (CST), used for the first time in 2000, are derived from the Key Standards.

The above two-tiered curricula priority system has the effect of creating two sets of "intended content", as the term is used in [S], one for all students, and an additional one for bright students. The relationship between intended content and what is taught is set forth in [S] as follows: "we can say with statistical confidence that what is stated in the intended content (be it a national curriculum or state standards) is, by and large, taught in the classrooms of most TIMSS countries." We have assumed the practices of teachers and school districts are consistent with the TIMSS findings, which means the basic curricular guide for all students is consistent with the "CC98-Basic" Key Standards.

4. METHODS

4.1 *Sample size and analysis of the test data*

Twenty-nine cohorts of students from 11 jurisdictions were analyzed, sixteen from the four Saxon districts, eight from the two control districts and five miscellaneous. Twelve cohorts included test data from five consecutive years, and seventeen from four consecutive years (Appendix). The general approach to analyzing this data was to apply a linear regression to each of these cohorts in order to determine the estimated rate of improvement of test scores (the slopes of the regression lines). Twenty-four of these cohorts were then analyzed using an independent sample t-test to each set of four slopes from the urban school districts which were early adopters of the CC98 curriculum and used the matching Saxon Math textbooks, as compared to the corresponding set of two slopes from the two (control) districts which continued to use the old CC91 curriculum and used the matching Quest 2000, MathLand and AnyTime textbooks.

Samples sizes for the four early adopter districts were (i) 6,672 students for the five-grade cohort of students tested in the 2nd grade in 1998 through 6th grade in 2002

(labeled cohort 98-2), and (ii) 6,398 students for the 4-grade cohort of students tested in the 3rd grade in 1998 through the 6th grade in 2001 (labeled cohort 98-3). The calculations for the two cohorts were performed for the category of "all students", and for the sub-category of "English learners" only. The corresponding sample sizes for the latter sub-groups were 2,227 and 2,174 respectively. In all cases the sample size for the control districts were approximately nine times as large (Table 3).

Table 3 - Independent Samples T-Test on the slopes of the four early adoption districts as compared to the slopes of the two control districts. All cohorts have 4 degrees of freedom

Cohort	Mean Slopes			t[d]	P[e]
	Early Adopt[a]	Controls.[b]	Diff.[c]		
98-2, All Students[f,g]	**7.95** (6,672)	**1.8** (62.2K)	**6.15**	6.64	0.004
98-3, All Students[f,h]	**8.73** (6,398)	**3.0** (58.2K)	**5.73**	4.98	0.014
98-2, English Learners[f,g]	**5.83** (2,227)	**-0.9** (19.4K)	**6.73**	5.39	0.009
98-3, English Learners[f,h]	**6.10** (2,174)	**-0.55** (18.4K)	**6.65**	3.58	0.031

a. Early adoption school districts Azusa, Sacramento, Baldwin Park, Basset – NPR Points per Year

b. Control school districts LAUSD, San Diego City SD - NPR Points per Year

c. Early adoption mean slope minus control mean slope

d. Standard errors separating two means

e. Probability of measuring a difference this large when the samples are taken from the same distribution

f. Number of students in parentheses

g. Five grade cohort

h. Four grade cohort

4.2. Comparing curricula

In order to compare the CC98 and CC91 curricula with that of the six leading TIMSS math countries, it is necessary to analyze the California curricula's intended content using the same General Topic Trace Mapping (GTTM) procedure used for the TIMSS countries. The North Central Regional Educational Laboratory (NCREL) website procedure recommended on page 16 of [S] was used for both curricula[18]. This procedure contains explanatory material on the intended content of each topic, and also provides guidelines for rating each topic, with 3 ratings possible. They are (i) *Emphasized* (several lessons) or (ii) *Taught* (at least one lesson) or (iii) *Not Taught* (incidental coverage only or no coverage). For the CC98 curricula, Key Standard topics were all given the "*Emphasized*" rating, and non-key standard topics were given the lower "*Taught*" rating. For the CC91 curriculum, where the same set of standards covered more than one grade, the procedure set forth in Endnote #6 [S, page 16] was used. Further, since the CC91 has no priority system in place, all standards were given the *"Emphasized"* rating. The authors made all the ratings decisions. The resultant set of Topic maps was then analyzed according to the criteria given in section 3.1. We also compared the total number of individual standards, recognizing that many standards fall into one topic.

4.3. *Comparing textbooks*

To evaluate the level of demand for the 6th grade, the more advanced subjects of ratio, proportion and rate were chosen, which fall within the topics categories of "Proportionality Concepts" and "Proportionality Problems" as well as the topic of "Equations and Formulas" through the close connection to slope and algebra. These proportionality topics are first introduced in the 6th grade in the California Key Standards curriculum. The actual number of pages devoted to instruction in the subjects of "proportion, ratio, rate", and the number of related pages devoted to student problem sets (class and homework) were counted. We repeated this procedure for the important pre-cursor subject of fractions.

5. RESULTS

5.1 *SAT-9 Tests*

Table 3 shows the independent sample t-test statistical results for the comparison of the four early-adoption districts (Azusa, Sacramento, Baldwin Park, Basset) with the two control districts (Los Angeles, San Diego). This calculation was performed for the five-grade cohort of students (98-2), and for the 4-grade cohort of students (98-3). The calculations for the two cohorts was performed for the category of "all students", and for the sub-category of "English learners" only. All the raw mean test score and population data as well as the results of linear regression and "standard error of estimates" calculations for the six jurisdictions are given in four tables in the appendix, one for each cohort shown in Table 3. The cohort populations are shown in parentheses, Table 3, and are calculated from the last year of each cohort.

The differences between the early-adoption and the control district mean slopes for "all students" as well as for "English learning students" were all within the range 5.73 to 6.73 National Percentile Ranking points per year (Table 3). This corresponds to a mean improvement difference of 22.9 to 26.9 NPR points over the course of the study. These differences are large relative to the variation within the samples. Statistical analysis confirmed that it is very unlikely that the results could have occurred by the vagaries of random sampling alone, as shown by the low "P" values in Table 3. Since the percentages of economically disadvantaged students in all six districts are similar and are very high (Table 4), and since all six districts enjoyed the same advantages of class size reduction and reduction in bilingual classrooms during this period, it is reasonable to conclude that the differences are real and have practical value.

Table 5 shows additional test data of interest. Three pilot schools within the LAUSD were allowed to adopt the CC98 curriculum and purchase Saxon Math textbooks. Ninth Street Elementary, with 99% economically disadvantaged and 79% English learners, improved by 39 NPR points from a low of 17. The other two improved by 29 and 23 NPR points, as compared to the LAUSD which only improved 12 points. The number of students is low, so a statistical treatment is not warranted, yet the improvements are notable.

Manhattan Beach Unified School District (USD) is a suburban district with very low EDS and EL. They were also an early adopter of the CC98 curriculum, purchased Saxon Math textbooks, and improved from 74 to 92 NPR (Table 5). This data suggests that a traditionally high-performing district can also benefit by a "quality" curriculum.

This is not surprising, since this curriculum is used by the six leading math countries of the world. The California state data is also shown as a reference in Table 5.

Table 4 - Demographic and Participation Data

District	EDS[a]	EL[b]	Tested/ Enrolled
Azusa USD	67%	41%	99%
Sacramento City USD	64%	27%	97%
Baldwin Park USD	76%	44%	99%
Bassett USD	78%	28%	98%
Los Angeles USD	76%	39%	95%
Annandale Elementary	90%	37%	98%
Ninth Street Elementary	99%	79%	97%
Eshelman Elementary	72%	22%	98%
San Diego City USD	56%	29%	97%
Manhattan Beach	4%	1%	98%
California State	47%	24%	97%

a - Economically Disadvantaged Student
b - English Learner (non-native speaking)

Table 5 - 5th Grade Elementary Schools and State of California, Improvement in California National Percentile Ranking (NPR) for Years 1998 – 2002,

Jurisdiction	NPR Mean Scores	Regression Slope	R	Number of students
Pilot Schools within LAUSD[a]				
Annandale Elem, LAUSD[b]	33-46-55-64-62[c]	**7.6**	0.943	41
Ninth St. Elem, LAUSD[b]	17-31-43-52-56	**9.9**	0.981	63
Eshelman Elem, LAUSD[b]	39-46-56-53-62	**5.3**	0.939	99
Los Angeles USD[d]	32-36-39-39-44	**2.7**	0.972	52.3K
Suburban School District[a]				
Manhattan Beach USD[b]	74-82-85-87-92	**4.1**	0.972	391
Statewide				
California State	43-49-51-55-62	**4.4**	0.984	464 K

a. 5th grade schools. 1999 score mean of 2nd & 3rd grade; 2000 score mean of 3rd & 4th grade; 2001 score mean of 4th & 5th grade; 2002 score 5th grade.
b. Early adoption schools with Saxon Math textbooks
c. Saxon Math textbooks removed for year ending 2002
d. 5th grade top, calculated the same as note "a"

5.2 *Curricula*

The topics map for the CC98 curricula, derived using the NCREL procedure[18], is shown in Table 2. This topics map incorporates the NCREL priority system, with a separate tabulation of topics deemed "Emphasized" (2's) and ones that are not (1's). Since the CC98 Framework clearly states that it is the Key Standards which should be emphasized, and further states that it is the Key Standards which should be the focus for students who are falling behind, the set of "Emphasized" topics derived from the Key Standards curriculum has been designated in this study as the "CC98-Basic" topics map required for all students. The "taught" set of topics, as tabulated in the next row of Table 2, has been designated the "CC98-Other" topics map, and the sum of the two is the same as the initial reform curriculum CC97. Total topic data, by grade, from the CC98-Basic map and the CC97 map have been summarized in Table 1, along with the total topic data from the CC91 curricula topic map[19], the TIMSS A+ composite [S], and the TIMSS U.S. States composite [S].

Based on topic totals from the early grades (Table 1) , the CC91, CC97 and U.S. States Composite all fail the "quality curricula" definition of section 3.1 on the basis of the *number of topics* and on *coherence*. These same three curricula also fail the *degree of repetition* definition, as shown in the last column of Table 1*,* although the CC97 comes close. The CC98-Basic curricula qualifies on the *number of topics* and on the first part of the *coherence* test, as shown in tables 1 & 2. A detailed examination of the Key Standards shows a high degree of coherence, as defined in [S], best shown by the preparation for the demanding topics starting in the 4th grade. The 1st grade has only 3 topics, allowing a focus on the memorization to automaticity of the addition and subtraction facts from 1 to 20, and counting to 100. The 2nd grade logically continues with addition and subtraction of 3-digit numbers, and starting to memorize the multiplication tables with 2, 5 and 10. Also simple multiplication problems, introduction to fractions and counting to 1000. The 3rd grade has the critical milestone of memorizing to automaticity the multiplication tables 1-10, multiplying multi-digit numbers times single digit numbers, adding and subtracting simple fractions, and introduction to decimals. In all three grades, memorizing to automaticity is accomplished by constant drill and problem solving. It is virtually impossible to carry out the 4th grade math standards without these automatic skills, much like the difficulty 4th grade students have if they cannot yet read to grade.

The final component of a quality curriculum definition*, level of demand of topics in the middle grades*, is evaluated using a 6th grade textbook comparison, as described in the next section. It is also interesting to examine the number of individual standards, as opposed to topics. For the 1st grade, "CC98-Basic" has 8 individual standards versus 40 for CC97. Overall, CC98-Basic has only 30% of the number of standards as CC97.

5.3 *Using the 6th grade textbooks to evaluate level of demand*

The results of the 6th grade textbook comparison are shown in Table 6. It can be seen that the Saxon 7th grade book, used in the 6th grade in California, devotes 102 pages of instruction to the demanding subjects of ratio, proportion, rate and the supporting algebra, and 116 pages to practice questions and problem sets. This may be contrasted with the books adopted to support the CC91 curriculum, Quest 2000 and MathLand, which devote

1 page and no pages respectively to instruction, and 13 pages and 6 pages to practice questions and problem sets.

Table 6 - Sixth Grade Textbook "Level of Demand" Evaluation for Proportions, Rate and Ratio: Number of Pages per Topics Group

Topics Group	Saxon[a] 8/7	Quest 6	Mathland 6
Proportions, Rate, Ratios, and related algebra[b]			
- Tutorial Instruction:	102	1	0
- Practice questions & homework problem sets:	116	13	6
Common & Decimal Fraction Operations			
- Tutorial Instruction:	84	1	5
- Practice questions & homework problem sets:	85	8	45

a. California uses Saxon 7th grade book for 6th grade.

b. Topics include Proportionality Concepts, Proportionality Problems, Percentages, Equations and Formulas

For Saxon Math, Table 6 also shows 84 pages of instruction in the pre-cursor subject of fraction operations and 85 pages for practice questions and problem sets. This may be compared with the Quest 2000 text at 1 page for instruction and 8 pages for practice questions and problem sets, and Mathland at 5 pages for instruction and 45 pages of practice questions and problem sets.

5.4 Saxon Math transition data

The SAT-9 test administered in the spring of 1998 was the first statewide test given in California after a four year hiatus and was the first ever to offer readily available, online school data on a grade-by-grade basis. This was a strong "wakeup call" to many administrators in the state who thought their math programs to be adequate. Baldwin Park was the worst of the four "early adopter" districts at 24 NPR points below the state average for the 2nd grade tests, with the other three at 19, 13 and 11 NPR points below (Appendix). The state average itself was 7 points below the national average at 43 NPR (Table 5). The other grade levels were also well below state averages, and administrators in these four districts took immediate and aggressive action.

Taking advantage of the fact that the old CC91 had recently been replaced with the initial reform curricula CC97, teachers in these districts were released from the requirement to follow the old CC91 curriculum and the matching textbooks (Mathland in Azusa, for instance), and urged to do the best they could on their own. In addition, all districts began to investigate alternate textbooks compatible with the CC97 reform curriculum. Sacramento instituted pilot studies of alternate textbooks in various classrooms in the 1998-1999 school year, including Saxon Math. The CC98-Basic curriculum with it's Key Standard priority system and it's focus on struggling students was adopted in December of that school year, providing teachers and administrators with more guidance as to topics which should be emphasized. Administrators also put pressure on the state to carry out an interim textbook adoption, resulting in the adoption of Saxon Math and two others in June of 1999. Administrators of all four districts selected and immediately ordered Saxon Math for classroom use in the 1999-2000 school year.

At the recommendation of Saxon, several of the districts purchased grade 4-6 textbooks one grade lower than the state-adopted level in order to ease the transition to this more rigorous curriculum. Sacramento purchased the state-adopted books, but instituted a placement program using the Saxon Placement Test. Almost all students were placed at a level at least one grade lower than the state adoption, and many were placed two grade levels below the state level. It took a number of years before Sacramento students were able to move up to the state-adopted levels. Sacramento used the Saxon Supplementary Activities material to assist teachers with lower performing students during this period.

Sacramento maintained a consistent goal throughout the SAT-9 period of eventually bringing all students up to the state-adoption levels, whereas Azusa was content to continue with the use of textbooks one-grade lower. The Azusa curriculum director has concluded that was a mistake. Our own analysis shows Sacramento was the best of the four districts, with both cohorts of all students starting at 30 NPR and ending at 64 NPR for a 34 point improvement, indicating the more demanding curriculum, resulting from the use of state adoption level textbooks in grades 4-6, provides superior preparation for the 7th grade even for economically disadvantaged and English learning students.

5.5 *The effective curriculum at the "early adoption" districts during the SAT-9 period*

The CC91 curriculum and textbooks were used during the 1997-1998 school year, and the resultant performance was measured by the first SAT-9 test in the spring of 1998. The initial reform CC97 curriculum was in place before the start of the 1998-1999 school year, and the CC98-Basic "quality curriculum" was adopted half-way through that school year. Teachers were released from the rigid pacing guides of the old CC91 curriculum and textbooks and told to do the best they could. Since virtually all students were performing below the requirements of the demanding CC97 curriculum by at least one year, and often two, the curriculum experts from the four districts assumed and believed the teachers focused on the simple basics in order to start catching up. More specific guidance to the teachers was provided by the adoption of the CC98-Basics curriculum half-way through that school year. Since the Key Standards set forth in CC98-Basic are a formal statement of simple basics in the early grades, it has been assumed the Key Standards represents the consensus curriculum during that year.

For the 1999-2000 school year, all these districts had the Saxon Math textbooks in place and knew about the CC98 curriculum. According to the curriculum experts, most students were using a Saxon book at least one year below the state level, and many were using a book two years below. Students were not being pushed ahead unprepared, which is one cornerstone of a quality curriculum. However, many 5th grade students in the 98-3 cohort were starting to miss some of the demanding middle grade topics since they were using a textbook one level lower. For the 2000-2001 and 2001-2002 school years, intense efforts were being made in the largest district, Sacramento, to move students up to grade level, using Saxon Placement tests and Supplementary Activities material. Still most students in the analyzed cohorts continued to use textbooks one grade level lower than the state adoption level. During these two years, for the cohorts 98-2 and 98-3, the lowered number of topics and the coherence, consistent with the Key Standards, became routine. Still, students increasingly started to miss some of the advanced and demanding topics of the state-level 6th grade.

In summary, with the exception of the demanding 6th grade subjects for many of the students, the curriculum during the SAT-9 years was consistent with the CC98-Basic

(Key) standards. The superior performance of the Sacramento district in all four cohorts (Appendix) indicates the aggressive policy of Sacramento in regard demanding topics can work even in an urban district having a majority of disadvantaged students.

6. DISCUSSION

Although the *content* of the particular set of Saxon textbooks used in California was judged an adequate match to the *content* of the CC98-Basic quality curriculum by the state CRP, the *teaching methods* used by Saxon had no particular relationship to the *teaching methods* used by the six leading countries. Thus the conservative conclusions of this study must be that (i) the *content* of the CC98-Basic Key Standard curriculum is the *content* of a quality curriculum and (ii) a jurisdiction wishing to reproduce these results can choose to employ a CC98-Basic type curriculum plus Saxon textbooks, or a textbook with similar teaching methods to Saxon, or a textbook or textbook teaching method from any of the original six leading countries. The Singapore textbooks are available in English, for instance.

The teachers in the four early adoption districts had no particular special training, yet they achieved remarkable performance improvement from their students. San Diego initiated a very ambitious teacher training program (Quick et al., 2003), yet their performance improvement remained relatively flat. It appears difficult to overcome the negative effects of an inadequate curriculum solely with teacher training. Regarding socio-economic status (SES), nothing in this study contradicts the finding that higher SES students do better than lower SES students for any particular curriculum.

7. SUMMARY AND CONCLUSIONS

This paper defines a "quality" curriculum based on the composite curricula of the six leading TIMSS math countries and on the TIMSS curriculum study [S]. The 1998 adoption California Key Standards curriculum (CC98-Basic), in combination with Saxon Math textbooks, was found to be a quality curriculum based on the reduced number of topics and on its coherence, minimum amount of repetition, and its level of demanding topics in the middle grades. It was also found that such a quality curriculum could be successfully transplanted from its Asian and European roots to a location with a vastly different culture and economy, despite warnings to the contrary [S, page 16], (Leung, 2005, page 212).

Four urban school districts with high percentages of economically disadvantaged and English learning immigrant students became "early adopters" of this new (to California) curriculum and purchased matching adopted Saxon Math textbooks. The performance of these four districts was found to be statistically superior to similar (control) districts which continued with the old 1991 California curriculum (CC91) and matching textbooks. The focus of this paper is on the time-dependent transition from far below to above average learning performance of these students over the 5-year span 1998-2002. A 6,672 member cohort of 2^{nd} – 6^{th} grade students from the four "early adoption" urban districts achieved a rate of improvement of 8.0 National Percentile Points per year over the 5-year span, as compared to the two control districts at 1.8 NPR points per year. An independent sample t-test on this data showed $t = 6.64$ and $p = 0.004$, thus verifying the statistical quality of this comparison. Similar results were obtained with a 6,398 member cohort of 3^{rd} – 6^{th} grade students, and for the English learners within each of those cohorts. All six districts had percentages of economically disadvantaged students

between 56% and 78% (weighted mean 68% for the Saxon districts), and English learners between 27% and 44%. An "early adoption" suburban school district showed an increase in NPR from 74 to 92 during the period 1998-2002, thus showing this type of curriculum also works well with the traditional high-performing students.

The issue of textbook influence was examined in some detail. It was found that a Content Review Panel (CRP), consisting of professional PhD mathematicians, played an important role in insuring that adopted textbooks were consistent with the content of the California quality curriculum. For the results reported here, it was the California CRP which played an essential role in deciding that 6th graders in California should be taught from a nationally marketed 7th grade textbook, and similarly for the 5th and 4th graders.

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APPENDIX

Four "early adoption" urban school districts and two control districts with similar demographics. Shows National Percentile Ranking (NPR) and number of students for each class. All students in each class took exactly the same SAT-9 tests.

Table A - Cohort 98-2, All Students

Year	Grade	Early Adoption Districts				Control Districts	
		Azusa	Sacramento	Baldwin Park	Basset	LA USD	San Diego City
1998	**2**	**32** 1,028	**30** 4,217	**19** 1,470	**24** 392	**32** 47.4K	**50** 10.5K
1999	**3**	**37** 798	**47** 4,110	**29** 1,460	**39** 453	**35** 57.5K	**58** 10.6K
2000	**4**	**40** 957	**50** 3,950	**36** 1,440	**42** 446	**35** 55.5K	**56** 10.7K
2001	**5**	**50** 971	**55** 3,940	**46** 1,430	**55** 445	**39** 55.3K	**54** 10.6K
2002	**6**	**57** 938	**64** 3,890	**59** 1,420	**57** 424	**42** 52.3K	**58** 9.92K
Slope[a]	**2-6**	**6.3**	**7.6**	**9.7**	**8.2**	**2.4**	**1.2**
R[b]	**2-6**	**0.9829**	**0.9600**	**0.9948**	**0.9683**	**0.970**	**0.5670**
Total Gain[c]		**25**	**34**	**40**	**33**	**10**	**8**
Std Error Est.[d]		**3.76**	**7.0**	**3.18**	**6.75**	**1.10**	**3.18**

Table B - Cohort 98-3, All Students

Year	Grade	Early Adoption Districts				Control Districts	
		Azusa	Sacramento	Baldwin Park	Basset	LA USD	San Diego City
1998	**3**	**28** 935	**30** 4,056	**22** 1,350	**27** 469	**30** 45.7K	**47** 10K
1999	**4**	**32** 861	**39** 3,950	**24** 1,340	**32** 464	**30** 52.2K	**47** 10.2K
2000	**5**	**46** 885	**49** 3,850	**34** 1,310	**35** 445	**35** 50.7K	**51** 9.96K
2001	**6**	**48** 860	**64** 3,820	**52** 1,270	**47** 448	**39** 48.6K	**55** 9.60K
Slope[a]	**3-6**	**7.4**	**11.2**	**10**	**6.3**	**3.2**	**2.8**
R[b]	**3-6**	**0.957**	**0.992**	**0.942**	**0.957**	**0.958**	**0.944**
Total Gain[c]		**20**	**34**	**30**	**20**	**9**	**8**
Std Error Est.[d]		**5.0**	**3.14**	**8.0**	**4.35**	**2.41**	**2.2**

a. Linear regression slope, units are "NPR Points per Year"; **b.** Linear regression correlation coefficient; **c.** Total actual improvement, in "NPR Points" **d.** Standard Error of Estimate; units are "NPR Points"

Table C - Cohort 98-2, English Learning Immigrant Students

Year	Grade	Early Adoption Districts				Control Districts	
		Azusa	Sacramento	Baldwin Park	Basset	LA USD	San Diego City
1998	**2**	**21** 458	**35** 134	**14** 678	**15** 151	**26** 23.5K	**33** 3,006
1999	**3**	**34** 277	**44** 1,265	**22** 449	**31** 204	**29** 32.8K	**39** 3,257
2000	**4**	**33** 437	**40** 1,219	**32** 777	**36** 196	**25** 28.6K	**36** 3,428
2001	**5**	**39** 429	**44** 1,177	**40** 769	**43** 137	**23** 22.8K	**31** 3,463
2002	**6**	**44** 405	**53** 1,018	**52** 703	**35** 101	**23** 16.5K	**34** 2,905
Slope[a]	**2-6**	**5.1**	**3.6**	**9.4**	**5.2**	**-1.2**	**-0.6**
R[b]	**2-6**	**0.939**	**0.861**	**0.997**	**0.878**	**0.762**	**0.311**
Total Gain[c]		**23**	**18**	**38**	**20**	**-3.0**	**1.0**
Std Error Est.[d]		**5.91**	**6.72**	**2.10**	**12.8**	**3.22**	**5.8**

Table D - Cohort 98-3, English Learning Immigrant Students

Year	Grade	Early Adoption Districts				Control Districts	
		Azusa	Sacramento	Baldwin Park	Basset	LA USD	San Diego City
1998	**3**	**25** 396	**22** 158	**17** 633	**20** 149	**24** 22941	**31** 2977
1999	**4**	**29** 361	**33** 1,204	**19** 372	**22** 158	**22** 27741	**28** 3231
2000	**5**	**39** 384	**35** 1,122	**27** 690	**24** 135	**21** 21716	**30** 3114
2001	**6**	**37** 343	**51** 1,093	**45** 642	**25** 96	**21** 15652	**30** 2780
Slope[a]	**3-6**	**4.6**	**8.9**	**9.2**	**1.7**	**-1**	**-0.1**
R[b]	**3-6**	**0.899**	**0.961**	**0.931**	**0.990**	**0.913**	**0.103**
Total Gain[c]		**12**	**29**	**28**	**5**	**-3**	**-1.0**
Std Error Est.[d]		**5.02**	**5.75**	**8.09**	**0.55**	**1.0**	**2.17**

a. Linear regression slope, units are "NPR Points per Year"; **b.** Linear regression correlation coefficient; **c.** Total actual improvement, in "NPR Points" **d.** Standard Error of Estimate; units are "NPR Points"

END NOTES

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William Hook
Biology Department, University of Victoria
Box 10, Shawnigan Lake, British Columbia
V0R 2W0, Canada
E-mail: whook@uvic.ca

Wayne Bishop
Mathematics Department
California State University, Los Angeles
5151 State University Drive, Los Angeles 90032-8204
California, USA
E-mail: wbishop@calstatela.edu

John Hook
Meiners Oaks Elementary School
Ojai Unified School District
1116 Avila Drive, Ojai
California 93023, USA
E-mail: hookj@vcss.k12.ca.us