Abstraction vs. Computation in Mathematics Education: Evidence from New Math

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Abstract

As artificial intelligence automates routine and computational tasks, should mathematics education focus more on abstract reasoning over computation? I study this tradeoff using the largest change in America's mathematics curriculum, the New Math movement of the 1960s. New Math shifted the K-12 math curriculum away from arithmetic toward abstract concepts such as set theory and formal logic. I exploit New Math's quick rollout, prompted by the Soviets' launch of *Sputnik 1*, and subsequent withdrawal to estimate abstraction's effect had on the set of abilities of individuals. Additionally, I determine if abstract and routine tasks are substitutes or complements in math education. This is the first paper to empirically analyze the New Math movement and offers evidence on a curriculum tradeoff facing modern educators.

JEL: I21, I28, J24, N32

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"The Soviets have put a satellite into space. It does not raise the specter of immediate danger. But it does raise deep concern—about our scientific and technical progress, our educational system, and our ability to remain the world's leading nation."

— Dwight D. Eisenhower, *Statement Upon Signing the National Defense Education Act*, 1958

I Introduction

Current innovations in artificial intelligence (AI) are calling into question what skills will be necessary in the future, similar to the effect of modern computing (e.g., Castex and Dechter 2014; Deming 2017). If we allow predictions of valuable skills drive current education reform, AI's automation of routine tasks creates debate of whether K-12 curricula should continue focusing on computational drills and arithmetic or shift to abstract concepts, currently kept to post-secondary education. Shifting to abstract concepts may strengthen reasoning and logic skills, but at the risk of not maintaining the necessary fundamentals to understand them.

The relationship between abstract and computational skills in mathematics remains unclear. The two serve as substitutes if learning abstract concepts, such as set theory and different number systems, have no spillovers to computation (Joensen and Nielsen 2009; Acemoglu and Autor 2011). This allows abstract concepts to crowd out routine skills. However, spillovers from abstraction to arithmetic allow the two to be complementary similar to Autor and Dorn (2013). This occurs if learning the logic of set theory, for example, allows students to better understand the rules of arithmetic. Changes in K-12 skills have the potential to show in the long-run in an individual's occupation as they are bundles of tasks requiring various abilities (Autor, Levy, and Murnane 2003).

I exploit the largest and best funded reform to mathematics education in the US being the New Math movement of the 1960s (Raimi 1996). New Math represented a temporary change in mathematics curriculum in America following the Soviet Union's launch of *Sputnik 1* in 1957. *Sputnik* intensified fear that America was falling behind the Soviets and caused what would become known as the second Red Scare. Prompted by fear that the US was falling behind technologically, the federal government passed the National Defense Education Act providing generous funding to US education reforms, especially in math and science. At the center of mathematics reform was New Math.

New Math was a change in curriculum from rote calculation and memorization to abstract concepts such as set theory, different number systems, and proofs for students as young as kindergarten. The curriculum shifted to teach third and forth year college math classes by the time students graduated high school in hopes of shifting the set of skills available in the US labor market towards more mathematicians, scientists, etc. While New Math programs received generous funding following *Sputnik*, backlash from mathematicians, teachers, and parents led to it being almost non-existent by the mid 1970s.

This paper investigates the shift in skills and tasks completed by individuals who were exposed to New Math in elementary and secondary school. I do this by exploiting the exogenous timing of implementation, spurred by *Sputnik*. I use historical documents from prominent New Math groups and state education departments in Ohio to determine individuals' exposure to abstraction. I follow the task literature and estimate New Math's effects on the composition of tasks one will later use in their occupation.

II New Math Curriculum

The introduction of New Math shifted the way mathematics was taught in K-12 from using math as a way of calculation to math as a logical system, more similar to how math is taught in universities. New Math curricula differed from this in three fundamental ways. First, New Math prioritized abstract mathematical structures such as set theory, symbolic logic, and alternative number bases over computation, algebraic manipulation, and Euclidean geometry (Kline 1973). New Math treated abstraction as a way to learn calculation rather than as advanced topics reserved for college courses.

Second, where traditional curricula aimed for computational proficiency through memorization and drills, New Math emphasized deductive reasoning to teach students why mathematical procedures work rather than how to execute them (Miller 1990). The third difference was in mathematical language and formalism. New Math introduced formal mathematical notation and terminology, often centered in set theory, in elementary school. Rather than teaching addition through counting, New Math taught addition through the union of disjoint sets, shown in Figure 1 for fourth graders. Another example is how the Pythagorean Theorem was taught using geometric decomposition rather than through a formula. This was done using Figure 2 which includes a rhombus inside of a square where angles y and x form a right angle. The area of the large square equals that of the the small square plus the four triangles in gray resulting in equation 1 which is the Pythagorean Theorem when simplified. Other examples of New Math teachings are in the curriculum appendix.

Figure 1: New Math Addition

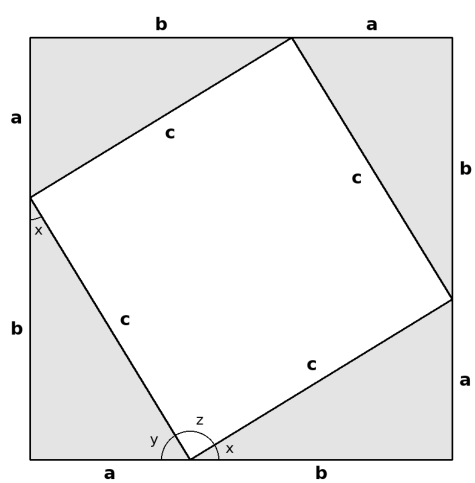
A binary operation is *commutative* if changing the order of the numbers operated on does not affect the result. Since the sum of two numbers is the cardinal number of the union of two disjoint sets, we can show that addition of whole numbers is a commutative operation. First we note that A∪B is the same set as B∪A, for any two sets A and B, because however we join A and B, we still have the same elements in the union. Second, suppose that a and b are two whole numbers, and that A and B are two disjoint sets whose cardinal numbers are a and b, respectively. Then by definition of addition:

a + b is the cardinal number of A∪B.
b + a is the cardinal number of B∪A.

These two cardinal numbers are the same, since A∪B = B∪A. Thus a + b is equal to b + a, no matter what whole numbers a and b are. This is what is meant by the statement, "Addition of whole numbers is commutative." This observation is important because, as we will see later, not all operations are commutative.

Note: Source: Greater Cleveland Mathematics Program 1962.

Figure 2: New Math's Pythagorean Theorem Figure



$$(a+b)^2 = a^2 + 2ab + b^2 = c^2 + 4\left(\frac{1}{2}\right)ab \tag{1}$$

Note: Source: Phillips 2014.

III New Math Exposure

III.A Beginnings

Beginning in the 1940s, many mathematicians affiliated with the American Mathematical Society (AMS) and the Mathematical Association of America (MAA) began voicing dissatisfaction with K–12 mathematics education in the United States. They believed school curricula focused excessively on rote arithmetic and calculation, neglecting newer mathematical developments such as set theory and abstract algebra.[1] In response, Max Beberman founded the University of Illinois Committee on School Mathematics (UICSM) in 1951. UICSM sought to develop a new pedagogy for high school mathematics and produced a wide array of instructional materials (UICSM Mathematics Project 1970). Beberman and UICSM designed the first curriculum of what would later become the New Math movement, also called the modern mathematics movement, emphasizing logic and number systems over computation (Phillips 2014).

A few years after UICSM's founding, the Soviet Union launched *Sputnik 1*, the world's first artificial satellite, on October 4, 1957. The launch sparked widespread fear in the United States, marking the beginning of the Space Race and leading to the creation of the National Aeronautics and Space Administration (NASA) the following year. This science oriented arms race affected all levels of American society, especially the education system, and as part of its response to *Sputnik* the federal government dramatically increased investment in science and mathematics education through the National Defense Education Act in 1958 and increased funding to the National Science Foundation (NSF). Investment from the federal government led to widespread changes among K-12 education. For example, the rate of mathematics instructional innovation in New York public schools nearly tripled in the fifteen months following *Sputnik*'s launch (Brickell 1961).

III.B Sputnik, NSF, and School Mathematics Study Group

The NDEA aimed to help America catch up to the Soviet Union in science and technology as the NSF's appropriation rose from \$40 million in 1958 to \$134 million the following year (Hunt and Editors 2025). Among the major recipients of NSF funding was Edward Begle's School Mathematics Study Group (SMSG), launched at Yale University in 1958 (Begle 1963). Inspired by Beberman's earlier efforts, Begle's SMSG collaborated with mathematicians and educators to produce K–12 textbooks that emphasized set theory, non-decimal number bases, and formal logic which states began incorporating into their official curricula (Phillips 2014). While initial efforts focused on high school, the approach eventually spread across all K–

[1] This is well documented in both peer-reviewed journals and books (e.g., Stanic and Kilpatrick 1992, Graham 2006, and Phillips 2014).

12 grades. By the mid-1960s, more than 85% of U.S. public school districts used New Math instructional materials at some level (Miller 1990).

III.C Greater Cleveland Mathematics Program and Other New Math Groups

While SMSG was the largest New Math group, many others were created following *Sputnik* to revamp math education across the US. The most influential in Ohio was the Greater Cleveland Mathematics Program (GCMP) created by the Educational Research Council of Greater Cleveland (ERC), an independent, nonprofit organization, founded in 1959 by Dr. George H. Baird. GCMP was ERC's first and largest program and sought to improve the quality of elementary and secondary math education in and around Cleveland, Ohio (ERC 1963).[2]

GCMP was a self-described New Math program emphasizing reasoning with its authors including mathematicians, math educators, and other experienced teachers.[3] The group was heavily inspired by SMSG and took recommendations from the National Council of Teachers of Mathematics and the MAA (ERC 1963). Different from SMSG, the GCMP focused on elementary math with its initial rollout of K-3 programs in January 1960 and expanded to K-6 in the 1961-1962 school year. Within two years of its creation, GCMP was taught to over two-hundred thousand students around Ohio (Baird 1961).

Similar to SMSG and GCMP, two other groups' New Math curricula were taught in Ohio, although at far fewer schools. These other groups are the Teachers of Elementary Mathematics Advisory Committee (TEMAC) and the Minnesota Mathematics and Science Teaching Project (Minnemast). Each of these groups were similar to GCMP being based off of SMSG and UICSM's programs, but focused on the elementary-school curriculum. However, both TEMAC and Minnemast consisted mostly of experienced elementary math teachers, unlike other New Math groups whose writers were majority mathematicians.

III.D Back to Basics Movement

Criticism of New Math emerged quickly.[4] Detractors argued that New Math was too abstract, introduced advanced concepts before students had mastered basic arithmetic, and was often incomprehensible to both students and their parents. Among the most prominent critics was Morris Kline, chairman of NYU's mathematics department, whose book *Why Johnny Can't Add* argued that New Math was hopelessly abstract and impractical. Nobel physicist Richard Feynman similarly contended that New Math was written

[2]The Educational Research Council of Greater Cleveland was later renamed to the Educational Research Council of America in 1967. For this reason, I refer to the group as the Education Research Council or ERC from this point on.

[3]A list of the guidelines and principles of the GCMP are listed in Table 1 and Table 2, respectively, in the appendix.

[4]Tom Lehrer, a famous satirical signer-songwriter and mathematician, released his song "New Math" in 1965 poking fun at the New Math Curriculum. In it he claims, "(New Math)'s so simple, so very simple. That only a child can do it!" Around the same time as "New Math", Peanuts, came out with seven daily comic strips emphasizing how New Math was written for mathematicians, not school children. These comic strips are included in the media appendix.

by and for mathematicians, not children (Feynman 1965). Critics also pointed out that most teachers lacked sufficient training to effectively teach the new curriculum, compounding confusion in classrooms (Stanic and Kilpatrick 1992).

These concerns resulted in the "Back-to-Basics" movement of the early 1970s, which advocated for a return to traditional arithmetic and skills-based instruction (Offner 1982). The momentum of this backlash accelerated the withdrawal of New Math from public schools, a process that had already begun in the late 1960s. New Math groups continually had their funding cut with SMSG ending in 1977. Although the ERC continued until 1984 with other programs, no GCMP documents were made after 1968.

IV Data

IV.A New Math Exposure

My measurement of New Math exposure comes primarily from a 1966 report, *Catalog of Educational Changes in Ohio Public Schools*, created by a collective of Ohio education groups and led by Daniel Stufflebeam. This report includes all significant changes to Ohio public schools and is based on the Ohio Educational Innovations Survey which was administered to all public school districts in Ohio in 1964. This report includes all changes to Ohio public schools from 1958 to 1964. Changes are separately identified as (1) instructional; (2) administrative, (3) pupil personnel services; (4) physical plant; (5) staff; (6); school-community relations; and (7) research.

As part of the Ohio Educational Innovations Survey, two questionnaires were sent out in early 1964. Together, these two questions include all education innovations made for all Ohio public schools from 1958-1964. These innovations are then separated by Stufflebeam's team to be one of the seven types of changes listed previously. Most important for this paper are instructional program changes. I gather information on whether a public school district was ever exposed to New Math from the reports of the first wave of the survey. When available, I combine that with information from the second survey to obtain the implementation year, grades taught, and short descriptions of the program.

Importantly, New Math had many versions as developed and dispersed by separate curriculum groups such as the UICSM, SMSG, GCMP, TEMAC, and Minnemast. Each of these groups are explicitly mentioned in Stufflebeam's report as being taught at some Ohio public school district while others use a general mention of new or modern math. I count all school districts which mention any of the New Math groups mentioned here, or more broadly new or modern math as having taught New Math. I obtain the school-year they implemented and the grades taught New Math from the second survey, when available.

Additionally, I cross-reference the Ohio report with documents from the GCMP, the most popular New Math group in Ohio. These documents each give a cross-section of all districts using GCMP's curriculum which initially began in January 1960, teaching only K-3. These schools then expanded to K-6 in the 1961-1962 school year.

I use the combination of these historical documents to determine which school districts ever implemented New Math and the exact known dates of implementation when possible. When exact dates of implementation and withdrawal aren't known, I imply the latest implementation and earliest withdrawal dates based off the available data sources which biases my estimate towards zero.[5] The Ohio report also allows me to check for potential confounders using all other programs they list under one of the seven types.

IV.B Census

I use restricted-access versions of the 1970, 1980, 1990, 2000, and 2010 decennial Censuses to obtain information on individuals' occupations, education, wage, and demographics. Importantly, all individuals have a Census Occupation Code corresponding to their current occupation. I link Census data to the Social Security Administration's Numerical Identification Files (NUMIDENT) to obtain detailed birthplace information not present in the Census. I restrict the sample to those in Ohio who were born between 1940 and 1975 to keep only individuals who I have the complete knowledge of their New Math exposure.

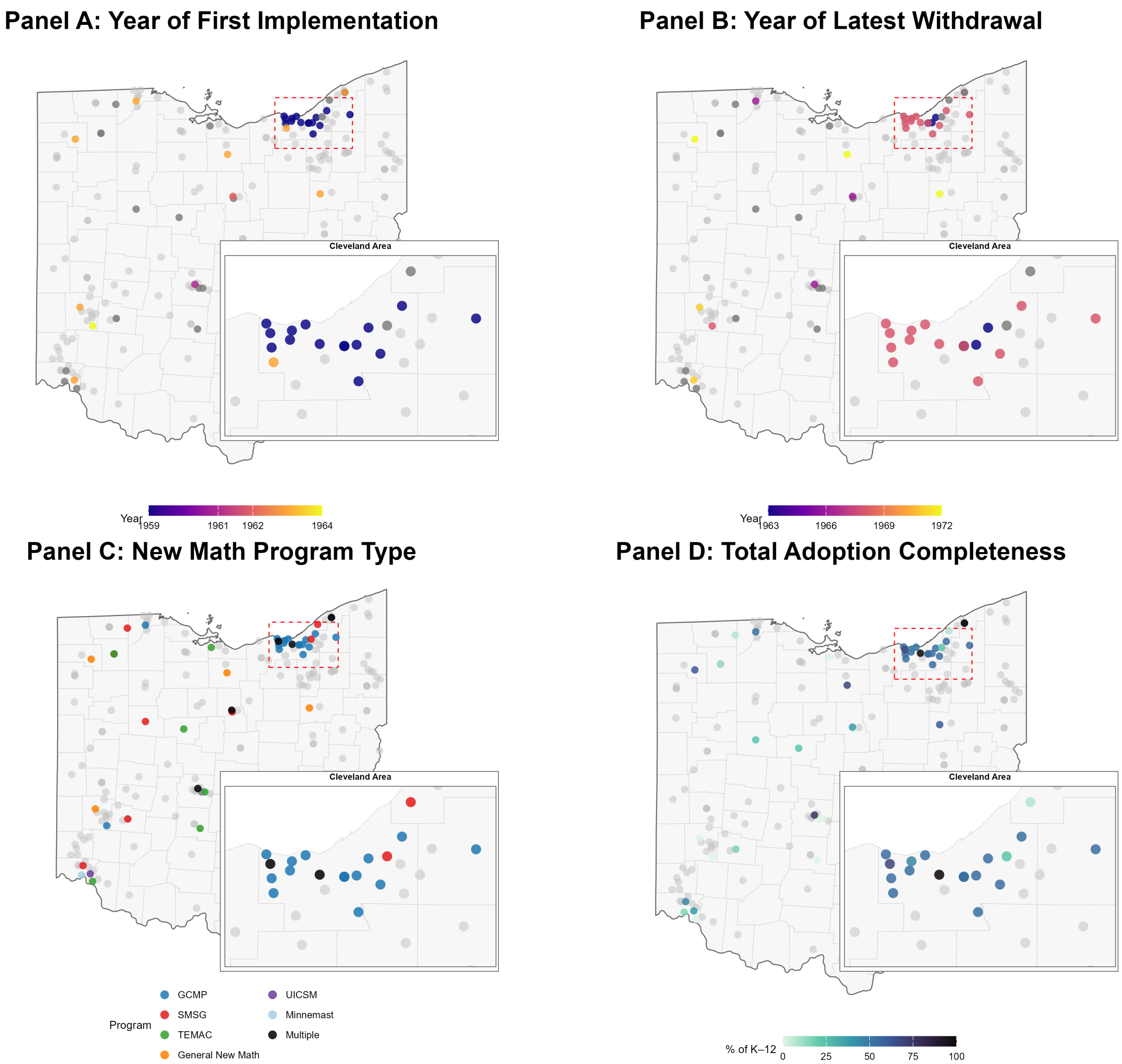
IV.C Occupation Tasks and Abilities

To determine the composition of skills and knowledge necessary for one's occupation, I use the US Department of Labor's Occupational Information Network (O*NET) which is commonly used in the task literature (e.g., Autor and Dorn 2013; Goos, Manning, and Salomons 2014; Deming 2017). The O*NET maintains average responses to occupation level surveys which include the amount of each ability or skill necessary to complete the job. These responses are reported at the Standard Occupational Classification (SOC) level which are linked to OOCs in the Census using David Dorn's crosswalk. Due to the long time horizon, I fix all occupation's skill composition at the year 2000.[6]

[5] More on how New Math implementation was imputed in the data appendix.

[6] Implicitly, this assumes a job's skill composition remains constant over time.

Figure 3: New Math in Ohio



Note: School districts with no implementation of New Math are represented by gray dots. Panel A reports the first year of any New Math implementation. Panel B reports the percentage of grades, K-12, which were ever exposed to New Math in the school district. Panel C reports which of New Math program was implemented in each school district. Orange dots represent districts which did not report any specific New Math program (i.e. UICSM, SMSG, GCMP, etc. Panel D reports which data sources each school district is included in. Sources: Science Research Associates 1962; ERC 1963; Stufflebeam et al. 1966; ERC 1968.

V Identification Strategy

V.A Extensive Margin

I first estimate the effect of any New Math exposure on one's occupational skills. I do this using a staggered difference-in-differences from Callaway and Sant'Anna (2021) in equation 2.

$$Y_{idt}^{j} = \alpha_0 + \alpha_1^{j} \text{ New Math}_{dt} + X_i'\delta + \mu_d + \mu_t + \varepsilon_{idt} \tag{2}$$

Y_{idt}^{j} is the amount of ability or task necessary for individual i's job who was born in the public school district d at time t. New Math$_{dt}$ is an indicator equal to one for individuals who are ever exposed to New Math based on the school district they were born into. X_i is a vector of individual demographic controls. μ_d and μ_t represent district and year of birth fixed effects, respectively. Standard errors are clustered at the district-birth-year level.

This model relies on the assumption that ability composition among individuals who are exposed to New Math would have evolved similar to those who were not exposed to new math. α_1^{j} gives the effect on occupational tasks of New Math at the extensive margin. If task j is abstract and task k is routine, then we would expect α_1^{k} and α_1^{l} to be of opposite signs if they are substitutes. If they were to receive the same effect from New Math's abstract curriculum, then they are complements.

V.B Intensive Margin

Next, I exploit the quick rollout of New Math, due to *Sputnik*, and differences in individuals' age at implementation to obtain quasi-random exposure to New Math. Using this, I estimate the effect of an additional year of New Math exposure on the types of job skills necessary for one's occupation using the seemingly unrelated regressions (SUR) model below.

$$Y_{idt}^{j} = \beta_0 + \beta_1^{j} \text{ Years of New Math}_{dt} + X_i'\delta + \mu_d + \mu_t + \nu_{idt} \tag{3}$$

The outcome, Y_{idt}^{j}, remains unchanged being the amount of a task j which is performed at i's job. Years of New Math$_{dt}$ is an exposure variable equal to the number of years of New Math an individual born in district d at time t was taught. X_i, μ_d, and μ_t are the same as in equation 2.

I estimate equation 3 using SUR across varying tasks j since there is correlation among abilities necessary for individuals' jobs. This results in error terms being correlated across abilities which I leverage for improved efficiency over running ordinary least squares individually for each task type. The specification in model 3 results in β_1^j being the effect of one additional year of New Math exposure for individual i on the probability of using ability j in their occupation. The relationship between β^k and β^l for abstract and routine tasks has the same interpretation as in equation 2.

VI Appendix

VI.A New Math Curriculum

Table 1: Basic Guidelines of the Greater Cleveland Mathematics Program

Guideline	Description
1	The basic program be suitable for use by all students.
2	The program have a continuous and systematic flow of mathematical concept formation from grades kindergarten through twelve.
3	The program originate at the lowest level of instruction in kindergarten or first grade and be continued through to grade twelve.
4	The teaching approach make the greatest possible use of the discovery method of teaching and provide continuous challenge and stimulation to the student.
5	The program be mathematically correct and pedagogically sound.

Note: Source: ERC 1963, pp. 9.

Table 2: Principles of the Greater Cleveland Mathematics Program

In writing the student and teacher materials, the authors have endeavored to create a program:

Principle	Description
1	That stresses reasoning and understanding.
2	That develops the basic properties of the number system.
3	That leads the child to discover patterns and relations for himself.
4	That uses precise definitions in order to develop the mathematical language.
5	That leads the pupil from the concrete to the abstract.
6	That gives the child an opportunity to discover mathematical principles for himself.
7	That makes use of the child's basic intuitive notions.
8	That takes advantage of the child's natural curiosity and creative imagination.
9	That is self-motivating.
10	That is structured on a continuous flow of ideas.
11	That is suitable for all students.
12	That is comprehensive.

Note: Source: ERC 1963, pp. 10–11.

Table 3: GCMP Sequence, Kindergarten–Grade 3

Concepts	K	1	2	3
Sets				
One-to-one correspondence	✓	✓	✓	✓
Equivalent and non-equivalent sets	✓	✓	✓	✓
Union of sets (addition)	✓	✓	✓	✓
Subsets	✓	✓	✓	✓
Set separation (subtraction)	✓	✓	✓	✓
Sets defining multiplication			✓	✓
Set partitioning (division)			✓	✓
Numbers and Numerals				
Cardinal numbers; numeral distinction	✓	✓	✓	✓
Numbers 1–10	✓	✓	✓	✓
Numbers 0–100		✓	✓	✓
Numbers 0–999			✓	✓
Numbers to millions				✓
Reading/writing numerals	✓	✓	✓	✓
Counting (by 1s; then skip counting)	✓	✓	✓	✓
Place Value				
Base-ten system		✓	✓	✓
Expanded notation		✓	✓	✓
Place value beyond 1,000				✓
Order and Relations				
Ordering and comparing numbers	✓	✓	✓	✓
One-more / one-less	✓	✓	✓	✓
Equations and inequalities		✓	✓	✓
Ordinal numbers	✓	✓	✓	✓
Addition of Whole Numbers				
Meaning of addition; basic facts	✓	✓	✓	✓
Properties of addition	✓	✓	✓	✓
Multi-digit addition (no carrying)		✓	✓	✓
Multi-digit addition (with carrying)			✓	✓
Subtraction of Whole Numbers				
Meaning of subtraction	✓	✓	✓	✓
Inverse relation with addition		✓	✓	✓
Multi-digit subtraction (borrowing)			✓	✓
Multiplication of Whole Numbers				
Repeated addition; set interpretation			✓	✓
Facts through 9×9			✓	✓
Multi-digit multiplication				✓
Division of Whole Numbers				
Partitioning; missing factors			✓	✓
Division facts			✓	✓
Multi-digit division				✓
Fractions				
Parts of a whole; equivalence	✓	✓	✓	✓
Common fractions		✓	✓	✓
Ordering and informal operations				✓
Measurement				
Time and money		✓	✓	✓
Advanced money concepts				✓

Note: From ERC (1963).

VI.B Data

Table 4: Implied New Math Exposure by District

	1	2	3	4	5	6	7	8
ERC (1963)	X	X	X		X			
Stufflebeam (1966)	X	X		X		X		
ERC (1968)	X		X	X			X	
Initial SY (K-3)	1959–1960	1959–1960	1959–1960	1963–1964	1959-1960	1963–1964	1964–1965	
Final SY (K-3)	1972–1973	1972–1973	1972–1973	1972–1973	1964–1965	1972–1973	1972–1973	
Initial SY (4-6)	1961–1962	1961–1962	1961–1962	1963–1964	1961–1962	1963–1964	1964–1965	
Final SY (4-6)	1972–1973	1972–1973	1972–1973	1972–1973	1964–1965	1972–1973	1972–1973	
Number of Districts	4	0	13	2	7	27	3	158

Note: Table generally describes the dates initial and final school years implied for each district's New Math curricula based on GCMP and Ohio education reports. There is some variation within columns based off the type of New Math taught (e.g., UICSM, SMSG, GCMP, TEMAC and Minnemast) as mentioned in Stufflebeam's report. The link to a specific New Math program also helps inform when certain grades were taught New Math due to the staggered publication of the programs curricula by grade level. GCMP programs are assumed to have been withdrew after the 1968-1969 school year and all other New Math groups after the 1972-1973 school years due to the SMSG closing in 1972. Sources: Science Research Associates 1962; ERC 1963; Stufflebeam et al. 1966; ERC 1968.

VI.C New Math in Media

Figure 4: Peanuts Comic Strips Referencing New Math (1964–1965)

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